Wireless World

RADIO • ELECTRONICS • ELECTRO-ACOUSTICS

JAN. 1943

1/3

Vol. XLIX No. 1

FREQUENCY MODULATION : NEW SERIES


GECALLOY
N.F. ALLOY POWDER.
GECALLOY NF ALLOY POWDER
is now used for practically all radio cores being manufactured in this country. It is an all-British Product, the result of extensive research and development work carried out during the last 15 years.
The use of a finely divided alloy of high magnetic quality represents a further advance in the science of Magnetic Powder metallurgy in comparison with all the various grades of iron powder, most of which previously have been imported.
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IN MAGNETIC POWDER
METALLURGY
MAIN ADVANTAGES of GECALLOY NF ALLOY POWDER and RADIO CORES.
1. Higher permeability.
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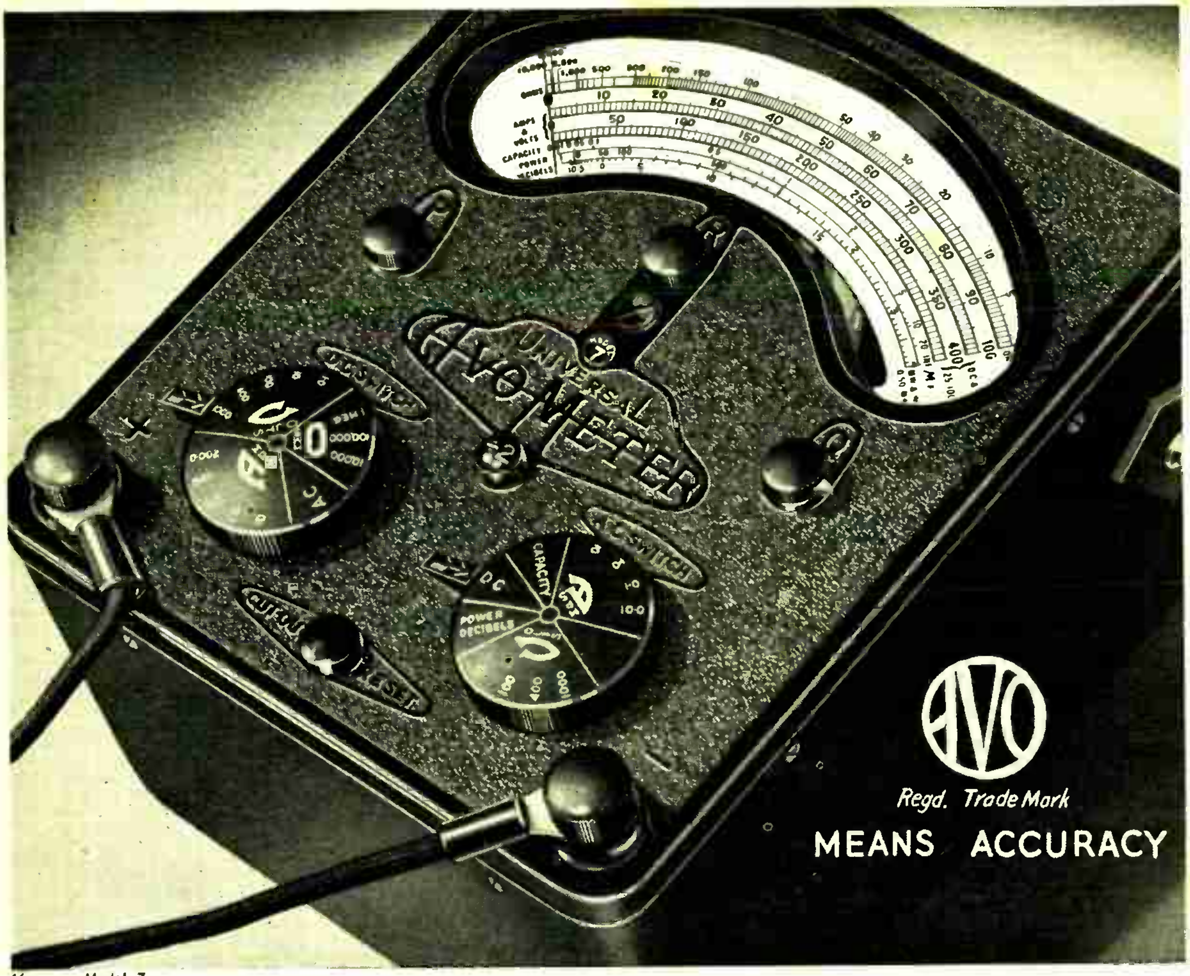
PROPRIETORS: THE GENERAL ELECTRIC Co. Ltd., OF ENGLAND



46-range Model 7
Universal AvoMeter

The Model 7 Universal AvoMeter (illustrated) is a compact combination electrical measuring instrument of B.S. 1st Grade accuracy. Its 46 ranges cover A.C. and D.C. amperes and volts, resistance, capacity, audio-frequency power output and decibels. No external shunts or series resistances. Protected by automatic cut-out against damage through overload.

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The world-wide use of "AVO" Instruments is striking testimony to their outstanding versatility, precision and reliability. In every sphere of electrical test work—laboratory, shop or out on a job—they are appreciated for their dependable accuracy, which is often used as a standard by which other instruments are judged. There is an "AVO" Instrument for every essential electrical test.

Sole Proprietors and Manufacturers:

AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT Co., Ltd., Winder House, Douglas St., London, S.W.1

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WHAT BIT TEMPERATURE SHOULD BE USED FOR 40/60 ALLOY?

This and numerous other queries are answered in reference sheet 2 of "Technical Notes on Soldering," published by the manufacturers of Ersin Multicore—the A.I.D. approved solder wire with three cores of non-corrosive Ersin activated flux.

Firms engaged on Government contracts are invited to write for a copy of this reference sheet and samples of Ersin Multicore Solder Wire.

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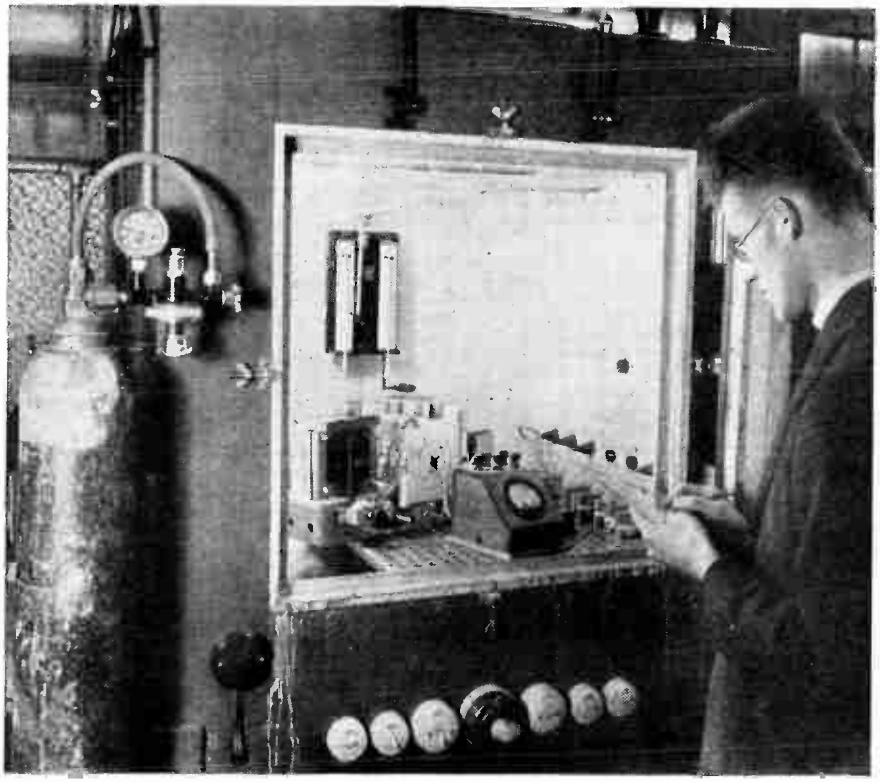
The Solder Wire with 3 Cores of Non-Corrosive Ersin Flux

MULTICORE SOLDERS LIMITED, BUSH HOUSE, W.C.2. 'Phone Temp.Bar 5583/4

Value proved by long service



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Wave Band Coverage 18m. to 2,000 metres, 5 watts output. Large 6in. Glass Dial. Separate tone and volume controls. Extremely good selectivity and sensitivity. Really "Hot" on Short Waves. Heavy Gauge Steel Chassis. Provision for extension Loud-speaker and Pick-up.

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Above prices include Purchase Tax

POCKET VOLTMETERS in case, good quality, 0–120 v., 0–12 v. nickel, with lead, **10/6** each.
.0003 VARIABLE CONDENSERS, 2-gang, ceramic insulation, complete in brass screening can. Ideal for short wave work. Worth 21/-. **7/6** each.
SHORT-WAVE VARIABLE CONDENSERS, mounted on porcelain base. Solid brass, split vane, long spindle. Normally 30/-. **15/-** each.
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AMERICAN 3-GANG VARIABLE CONDENSERS. Aluminium screened with trimmers, two sections .0003, one section .0002, **10/6** each.
DUAL H.F. CHOKES, a bargain, **3/-** each.
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Don't miss this opportunity. These prices cannot be repeated. All goods are brand new. Guaranteed best quality. Close Tolerance.

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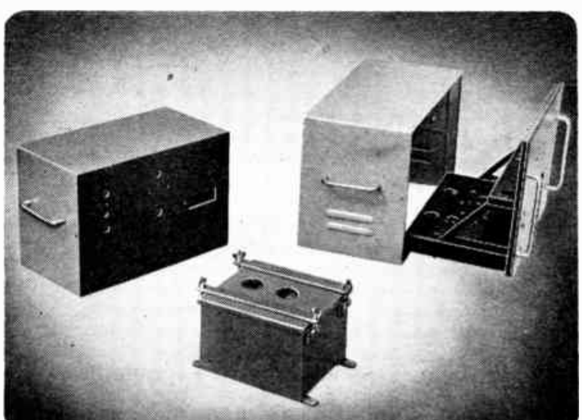

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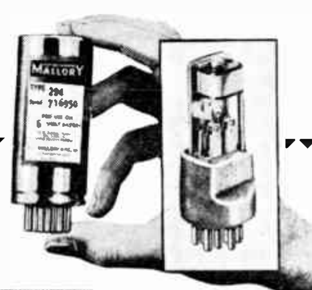

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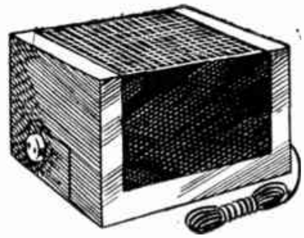
Type R.M. 80/150



Input: 230v. A.C. 50~
Output: 80, 100, 120, 150, 230v. D.C.
Incorporating Westinghouse Metal Rectifier. In strong steel case, well ventilated ... ... Price **5 Gns.**
Post and packing 3/6 extra.

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Finest quality. Turn movement. 1¾in. spindle. **2/6**

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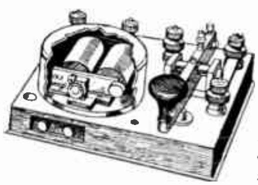

Made for professional use. All parts of heavy brass mounted on mahogany base. Platinum contacts. A robust unit which will give years of service ... **40/-**

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The best quality obtainable
8-pin International Octal ... each **1/3**

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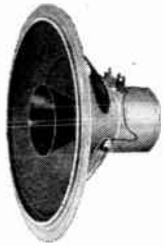
200/250 v. 75 watts **12/6**

PIEZO-CRYSTAL *Hand—Table* MICROPHONES

See December issue for details. **82/6**

Good Quality Components by PHILIPS

PHILIPS High Quality SUPER SENSITIVE P.M. SPEAKERS



These brand new speakers are fitted with concentrically mounted Hi-note Diffusers. 8½in. cone. Complete with Pentode Transformer. Price **32/6**

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15 mfd. at 275v., and 50 mfd. at 320v. each **12/6**

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Non-drift air dielectric, 60 mmfds., suitable for S.W. work. Price **1/3**

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Brand new, well-built chokes, 60 ohms D.C. resistance 400/120 m.a. Core size: 2in. × 1½in. × 1in. each **5/6**

Also 400 ohms D.C. resistance 60 m.a. Core size: 1½in. × 1in. × ⅞in. ... each **3/6**

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700,000 ohms, with 2-pole M and B Switch **4/6**
100,000 ohms, less switch **3/6**

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3-Gang 0.0005 mfd. without trimmers. As used in Philips well-known Push-Button receivers. Price **4/6**

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450 ohms and 10,000 ohms ... each **6/6**

PHILIPS HIGH VOLTAGE TRANSFORMERS

Robust in construction; weight approx. 13 lb. Dimensions: 5¾ × 5¼ × 4¼in. Specification: 350-0-350v., 70 m.a. Four tappings giving 4v. 3 amps., 6.3v. 4 amps., 4v. 0.65 amp. and 4,000 v. at 3 m.a. Input 100/250. Free wiring diagram. Carriage forward. Price **32/6**

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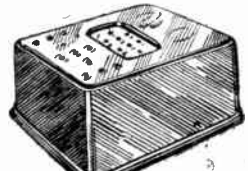
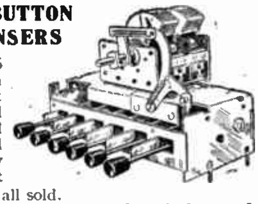
Model E25A
for 200-250v. A.C. 40-100~



Tappings, 40, 60, 80, SGH, 100, SGL, 125v. These well-known H.T. Mains Supply Units are fitted in handsome bakelite cases. Here is an opportunity for battery set owners, who have A.C. mains current available, to be independent of the battery situation. Owing to post and rail conditions these are available TO CALLERS ONLY. Price **70/-**

PUSH-BUTTON CONDENSERS



The .0005 6-button Front Manual Control Model recently offered at 10/6 are all sold. We can now offer a **.0003** mfd. **2-gang 6-button** Condenser as illustrated, but with **SIDE** manual control. Price **15/6**. Also **.0005, 3-gang 8-button at 17/6.**

6 PUSH-BUTTON MECHANISM only UNIT

Complete with buttons **4/6**

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ROLA 8in. P.M. without transformer ... **25/-**

CELESTION 8in. P.M. Pentode Output. New **25/6**

MULLARD EA50 DIODES

60 mm. × 12 mm. overall. 6.3v. heater at 15 amp. ... ... Each **10/6**

OAK SWITCHES

2½in. spindle. Complete with knob:
4-way, 2-bank with connecting block ... **4/6**
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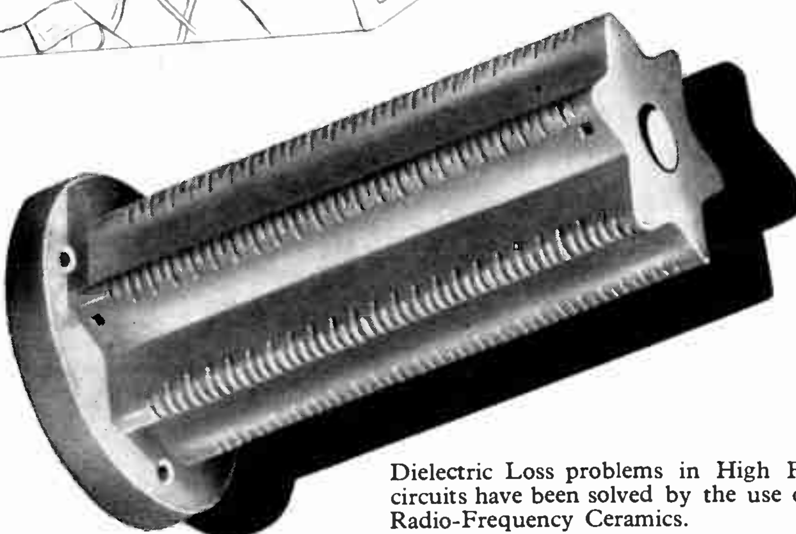

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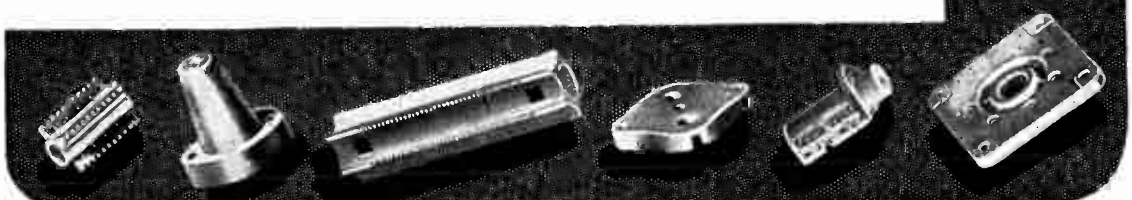

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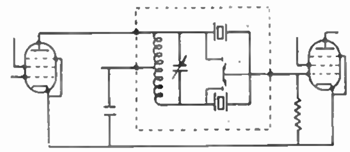
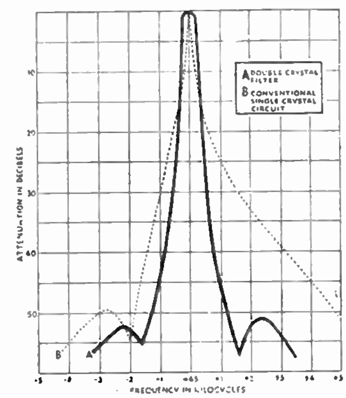


BAND-PASS FILTER CIRCUIT

Above is shown the fundamental circuit similar to that employed in the Eddystone 358X receiver. When in circuit the band-width is 300 c/s, front panel control allowing optional use of normal I.F. selectivity, band-width 5 Kc/s.



SELECTIVITY CURVE "A"

shows the steep sides and flattened top response curve of the Band-pass Filter. Compare the normal crystal gate (Curve B) with its typical sharp peak necessitating constant tuning adjustment with the slightest signal frequency variation. Note the symmetrical rejection given by Curve "A" as opposed to the uneven tail effect of Curve "B."

In the 358X version of this famous receiver a Band-pass Crystal circuit is employed giving high selectivity and complete rejection of unwanted adjacent signals. Furthermore the double crystal circuit avoids the extreme "peaked" effect of the conventional crystal gate, allowing easier tuning and accommodating some frequency drift of the wanted signal. These advantages are readily appreciated by operators familiar with the hair-breadth tuning of the normal filter.

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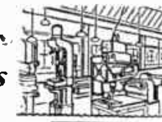
From Footlights  *to Factory*

IN town to-night—at famous theatres and fashionable restaurants you will find Trix Sound Equipment. Like the war workers in the great factories, they all trust the reliability of Trix.

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Illustration shows a TRIX 30-watt Amplifier with radio. There are TRIX Amplifiers from 5 to 500 watts.

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A NEW 38 RANGE UNIVERSAL METER

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A.C. VOLTS. 6 ranges from 0—2.5 to 1,000 v.
OUTPUT. 5 ranges from 0—2.5 to 500 v.
D.C. CURRENT. 5 ranges from 0—1 mA to 2.5 Amps.
A.C. CURRENT. 5 ranges from 0—1 mA to 2.5 Amps.
RESISTANCE. 3 ranges from 1 ohm to 1 megohm with internal battery.
RESISTANCE. 1 range from 1,000 ohms to 10 megohms with external 60 volt battery.
DECIBELS. 6 ranges from —22db to plus 60 db.
METER. 5 Scales covering A.C. and D.C. Measurements and also Ohms and Decibels.
SCALE LENGTH. Outer scale is 3½ inches long.

TAYLOR MODEL 90
Supplied complete with leads and test prod, internal battery and instruction book.

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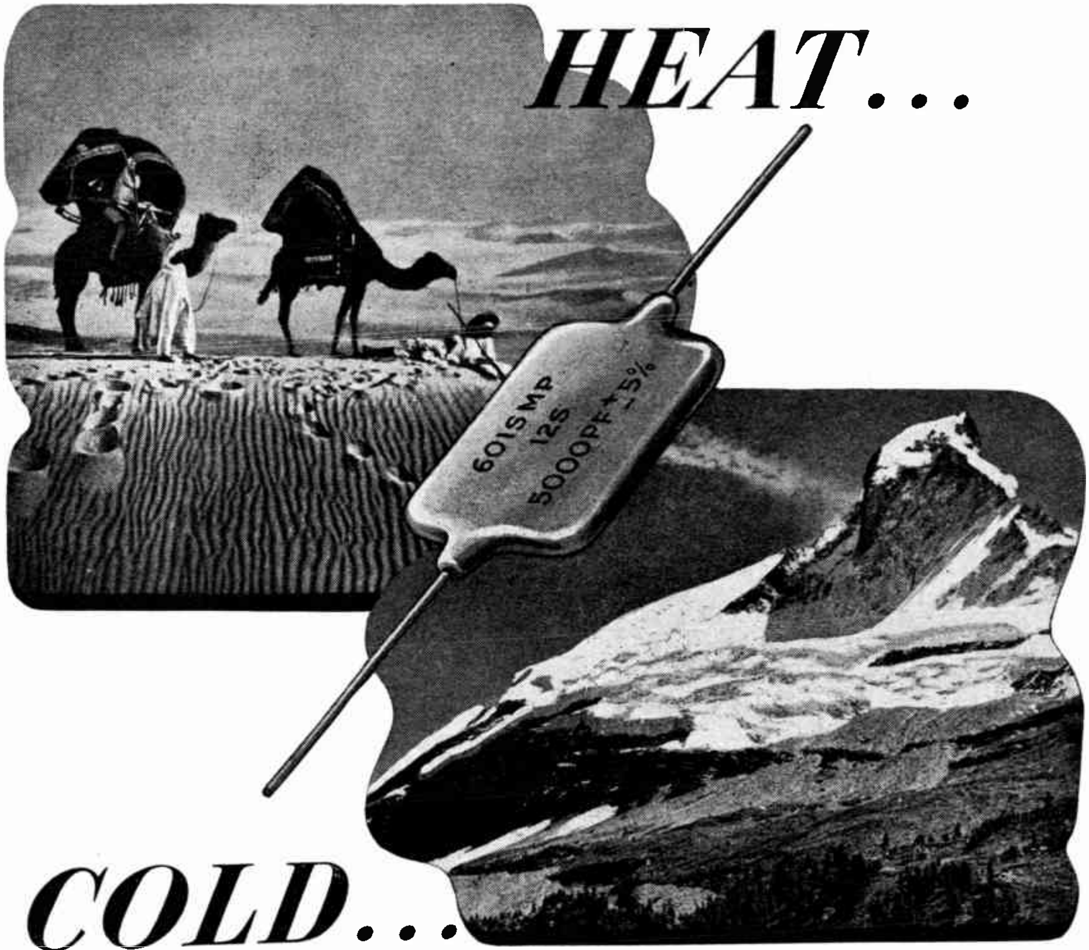

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20,000 ohms	... ...	**4/-**
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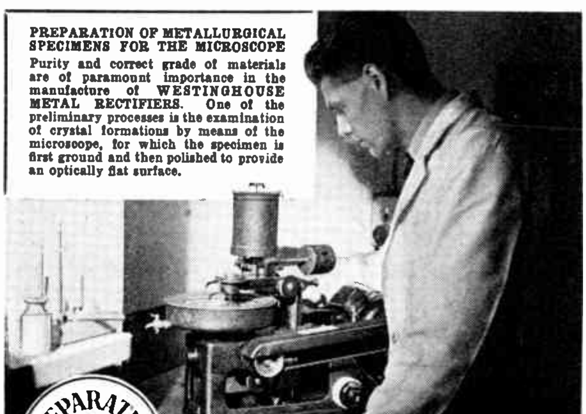

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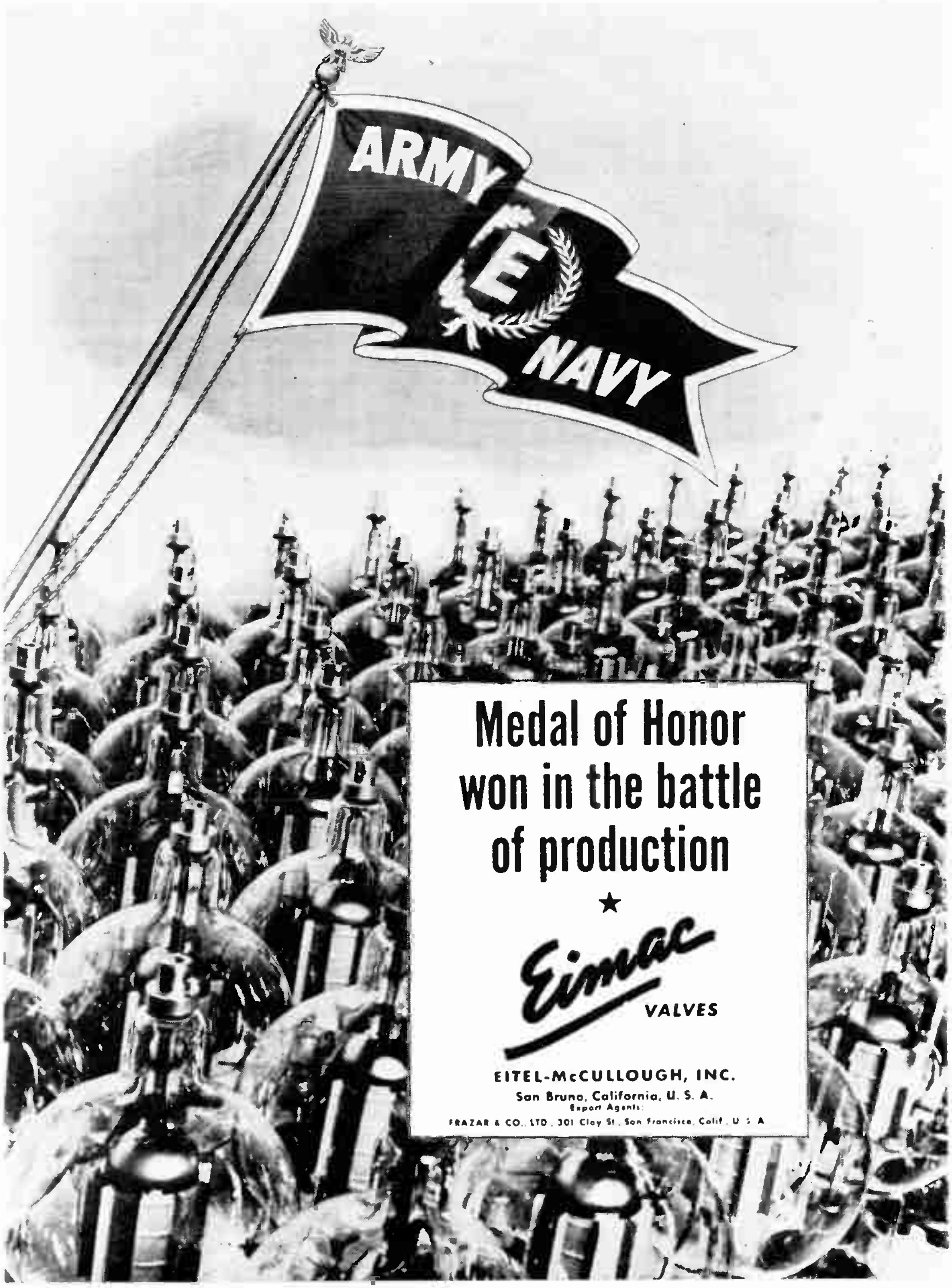
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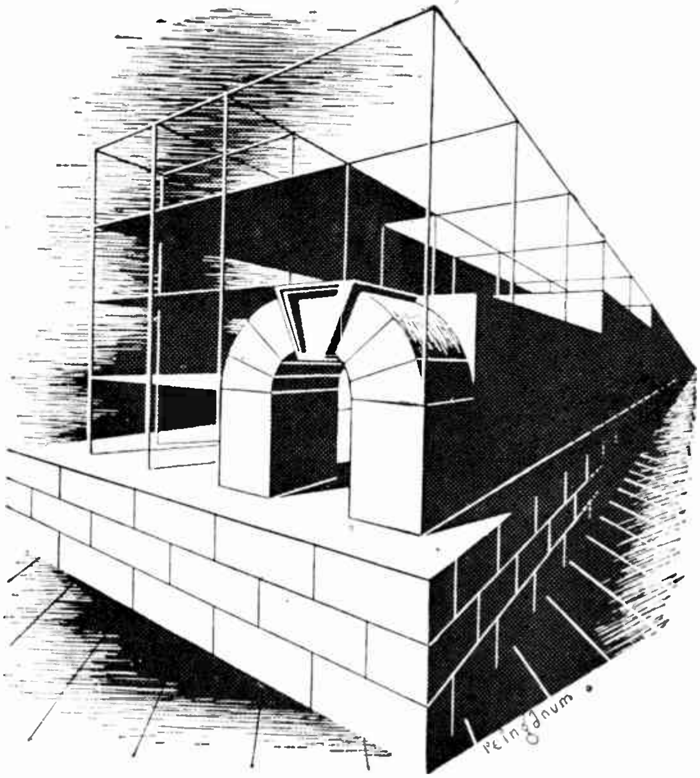

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Broadcast Receiver Maintenance

Economy in the Use of Wireless Resources

IN the issue of this journal for last August we expressed the view that the time had come to take drastic steps to ensure the continuance of broadcast reception. Since that time there has been no improvement; on the contrary, the position has deteriorated, in spite of the release (at the time of writing, on an apparently rather disappointing scale) of American Lease-Lend valves. It is believed that the number of broadcast sets now out of commission has reached a really significant figure, and, unless effective measures are taken now, the value of broadcasting as the most rapid means of disseminating information will be seriously reduced.

When writing on this subject in August, we examined the relative advantages of the two most obvious schemes for maintaining listening facilities for the majority of the population. The alternative plans were: (1) To devote a sufficient proportion of our wireless productive capacity to the manufacture of valves and components for replacements to keep existing receivers in working order, and (2) to design and mass-produce an extremely simple "austerity" receiver to replace broken-down sets. The second plan was admitted to be extravagant in raw materials, but it was suggested that it overcame the shortage of the skilled servicemen who would be required for the satisfactory operation of the first plan. An ample supply of components is of no avail if there is no one with sufficient skill to diagnose faults and make replacements.

The use of the word "alternative" was perhaps unfortunate. It was not intended to suggest that either plan should be adopted to the total exclusion of the other. Clearly, it is uneconomic under present conditions to substitute a brand-new receiver for one that could easily be restored to working order by fitting a standard valve or component of a type that can still be efficiently produced. But it is equally uneconomic to devote many precious man-hours to the diagnosis of a fault in an out-of-date receiver, and then to spend many more skilled man-hours in producing inefficiently the replacement part that is needed. In our view, there is room for both the plans to work side-by-side. What proportion of our productive capacity should be devoted to each scheme is a matter for discussion, but there seems to be a clear case for devoting some of that capacity to the manufacture of a simple "austerity" set. As far as producing replacements for sets that are economically repairable is concerned, we should concentrate on valves; also on reservoir and smoothing condensers.

Wartime Economies

In urging the importance of maintaining broadcast receivers in commission we are not unmindful of the needs of the Fighting Services, which must, of course, come first. Before asking for an allocation of some part of our national resources for civilian needs, we must make sure that what we already have is being used to the best advantage, and above all, that there is no waste.

Doubts have been expressed as to whether, in spite of the regulations, the American Lease-Lend valves are in fact being used solely as replacements. A correspondent instances the fact that, by a Ministry of Supply Order, a defective and unrepairable domestic boiler can only be replaced by a new one after making a declaration on an official form. He suggests that similar precautions should be taken in the supply of replacement valves. That seems to be an unnecessarily cumbersome procedure; would it not be sufficient to require that a "dead" valve should be surrendered when a replacement is purchased?

More economy in the use of wireless receivers might be practised by some sections of the public, who still seem to regard broadcasting merely as an all-day background to other activities. The B.B.C. could do good work in encouraging more selective listening, and in explaining what is being wasted when a wireless set is used unnecessarily.

Frequency Modulation—1

THE NATURE OF AN FM CARRIER

By
CHRISTOPHER TIBBS,
Grad.I.E.E.

In this article, the first of a series on FM, the properties of a frequency-modulated waveform are dealt with. Sidebands are discussed, and the way they are depicted by the panoramic monitor is described.

UNTIL comparatively recently amplitude modulation was regarded as the only satisfactory means of impressing intelligence on a carrier wave. During the last twenty-five years the other two systems, frequency and phase modulation, have often been discussed, but until 1936 nobody had been able to demonstrate any reasons which would warrant a departure from amplitude modulation. However, in that year Major Armstrong published a paper[2] in which he made some important claims for one of the neglected systems. He showed that the use of wide-band frequency modulation produced a remarkable improvement in the signal-to-noise ratio. Since that time FM has made rapid progress and is to-day being used by many new commercial broadcast stations springing up in all parts of the United States. The results obtained with FM are claimed to be so superior in both signal-to-noise ratio and reproduction fidelity that the ordinary amplitude modulation receiver has been rendered virtually obsolescent.

Most of the initial work on FM was done in or near New York, where the listening conditions are bad. The screening produced by immense steel-framed buildings, coupled with extremely high static levels and a lack of satisfactory aerial arrangements, provided a hothouse atmosphere for the forcing of any system offering a reasonable chance of providing the flat dweller with interference-free reception. Comment is sometimes made on the number of American flats equipped with central receivers and built in two-programme loudspeaker systems. One of the reasons for the popularity of this method of providing radio entertainment is the extreme difficulty experienced in obtaining satisfactory reception in flats which are part of a vast honeycomb packed with every imaginable type of electrical equipment, from hundreds of vacuum cleaners to express lifts.

Frequency modulation is claimed to be the almost perfect counter to these conditions. It offers an improvement in signal-to-noise ratio of more than 1000 to 1 on an equivalent amplitude modulation system. Coupled with this it also provides high-fidelity reception. Working on the ultra-short-wave band, it is above the frequency spectrum covered by most forms of natural and man-made static.

Reception conditions in New York, with its giant steel-framed buildings, provided a hothouse atmosphere for the forcing of any new system which would eliminate the background of interference

Properties of FM.—In the September issue of this journal the author discussed and compared the closely related systems of frequency and phase modulation. In view of the subject matter covered then, it is proposed to confine the present investigations entirely to frequency modulation.

The diagrams shown in Fig. 1 illustrate the manner in which intelligence is communicated by a frequency-modulated carrier. With the aid of these diagrams it is possible to make a number of deductions relating to the general nature of a frequency-modulated transmission. All the more important features are brought out by the following observations. The carrier frequency is steady at its mean or unmodulated frequency until modulation commences. The application of modulation causes the carrier to swing above and below its mean frequency. The amount of this frequency swing (i.e., the deviation amplitude) is in direct proportion to the amplitude of the modulating signal. The number of times, or the frequency with which the carrier swings above and below its unmodulated value is directly controlled by the frequency of the modulating waveform. It should be noted that the actual deviation frequency has no connection whatsoever with the frequency of the modulating signal.

Another important point is demonstrated in Fig. 1(b), namely, that the carrier amplitude remains constant regardless of the modulation. The general nature of a frequency-modulated carrier is well summed up in the following definition. A frequency-modulated transmission is one in which there is no amplitude modulation of the carrier, and in which the frequency fluctuations faithfully portray the modulating wave shape.

Frequency modulation is by no means a recent invention, it has in fact been discussed ever since the use of a modulated continuous carrier wave became a practical proposition. Early attempts to develop the system were based on the idea that by frequency modulating the carrier to a small degree, say a maximum deviation of only 1,000 cycles, it would be possible to reduce the bandwidth required by a broadcast station. In this way it was hoped to increase the number of stations on any given band. These early attempts were brought to a conclusion in 1922 with the first mathematical treatment of frequency modulation.

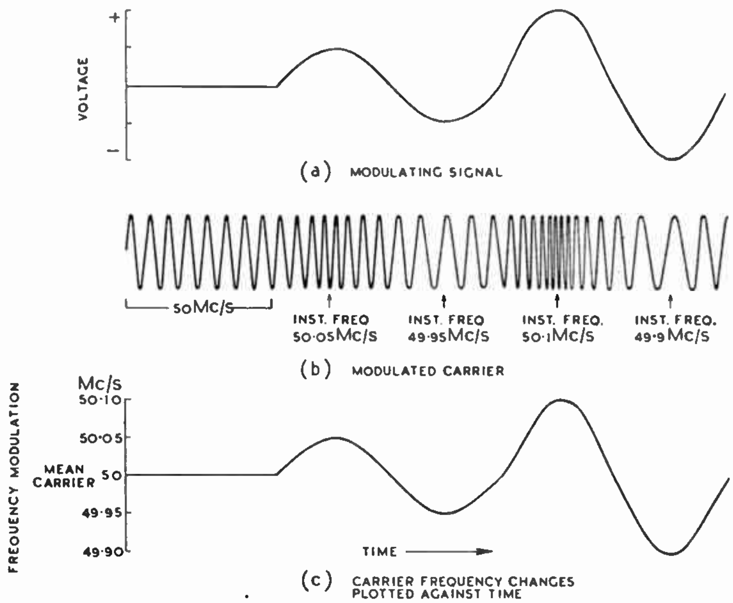

Fig. 1. Diagrammatic presentation of the general nature of a frequency-modulated carrier.

This paper, published by Carson[1], proved that these attempts were based on a fallacy, and that the bandwidth required is at least double the highest modulation frequency.

For a number of years FM was regarded as of no practical value. However, in 1936, E. H. Armstrong published a paper[2] in which he set forth frequency modulation not as a method of cramming more stations into the broadcast band, but as a means of reducing the level of every type of interference. He showed that by employing a deviation several times that of the highest modulating frequency, with, of course, suitable means of demodulation, there was an amazing improvement in the signal-noise ratio normally experienced with amplitude modulation. It is this system, now known as wide-band frequency modulation (FM for short), which is being so successfully employed in America.

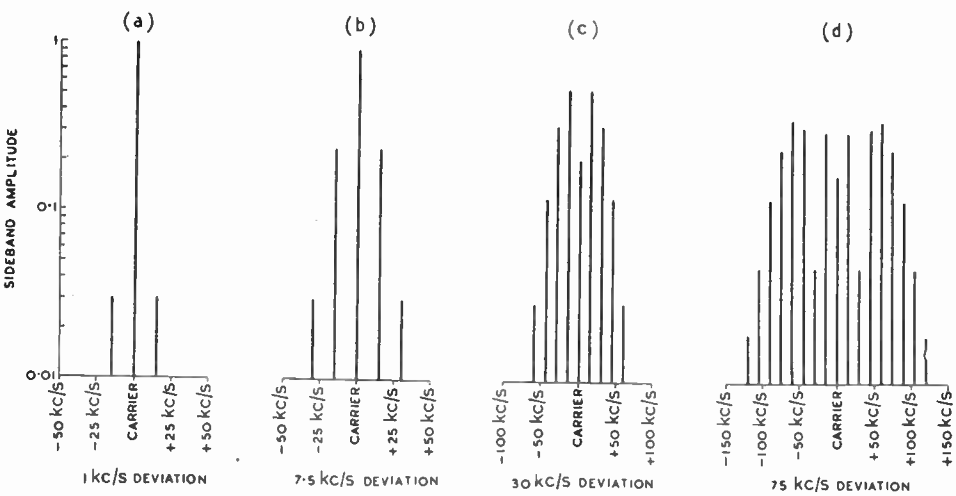

Fig. 2. Sidebands resulting from the frequency modulation of a carrier. The examples are calculated for 15 kc/s modulation and worked out from the formula given in the appendix.

FM Sidebands.—The failure of the early engineers who attempted to develop the system centres round their inability to grasp the full importance or even the existence of FM sidebands. It is proposed to deal with them at this stage, partly on account of the interesting historical sidelight they throw on the art, but primarily because it is the only way of explaining a number of important phenomena.

When a carrier is modulated it appears to the observer as though it is merely necessary to alter forcibly either the carrier amplitude or its frequency, depending on the type of modulation being used. As far as an examination of actual waveforms is concerned, this is all that happens; if, however, any serious investigation is to be undertaken, it is necessary to make use of the sideband theory. According to this theory, when a carrier is modulated it remains at its unmodulated frequency and some additional waveforms are brought into existence. These new components, or, as they are termed, the sidebands, interfere with the carrier in such a manner that the resultant combined waveform varies in either frequency or amplitude as required. If the new and additional waveforms are unable to exist for any reason whatsoever, then there will be no signal to interfere with the original carrier and so cause it to vary in the manner desired. This would account for the fact that an AM receiver with a passband which is too narrow to transmit the sidebands fails to reproduce the modulation. Without the sidebands the carrier remains at its steady or unmodulated value. In short, remove the sidebands and the modulation is suppressed.

Regardless of whether amplitude, frequency or even phase modulation are being employed, it is essential that the sidebands which accompany all forms of modulation

The Nature of an FM Carrier—

are passed by the receiver tuned circuits.

The only satisfactory method of arriving at the actual values of these sidebands is mathematically. This is especially the case with frequency and phase modulation, where they are large in number and extremely complex. There have been a number of papers dealing with the calculation of FM sideband amplitudes[3, 4, 5]. The equation, which has been developed by Roder, for a frequency-modulated carrier is set out in the appendix.

Fig. 2 shows a number of examples which have been calculated with the aid of Roder's formula. It should be noted that there are an infinite number of sidebands, but that for clarity only those with an amplitude greater than 1 per cent. of the unmodulated carrier value have been shown. These sidebands occur at intervals equal to the modulating frequency f_{mod} and on either side of the unmodulated carrier (i.e., at frequencies of $\pm f_{mod}$, $\pm 2f_{mod}$, $\pm 3f_{mod}$ . . . . $\pm nf_{mod}$). There are sidebands of quite considerable amplitude above the maximum carrier deviation frequencies. These are necessary, as the waveform resulting from the fusion of the basic carrier and its sidebands will have a frequency within the band they embrace. The sidebands beyond the maximum deviation frequencies are therefore required in order that the final waveform, of which they form a component part, may be "pulled" to its maximum deviation.

The apparently random fluctuations in amplitude, which occur between adjacent sidebands, are the result of the extreme complexity of their phase angle and vector diagrams. When there is no modulation all the sidebands are dormant and have zero amplitude. As soon as the carrier is modulated a single pair of sidebands or a small group of sidebands spring into being, at the same time the amplitude of the carrier itself falls. The result is that the combined waveform is "pulled" from the unmodulated carrier frequency towards that of the sidebands existing at that instant. The amplitudes of both sidebands and carrier are balanced to a nicety, thus maintaining the combined wave at a constant amplitude as its frequency is varied (i.e. avoiding spurious amplitude modulation.)

The Panoramic Monitor. — In order to ensure that the deviation of a frequency-modulated transmitter does not exceed the specified limits (normally a maximum of ± 75 kc/s) some form of continuously operating monitor is required. This equipment, generally known as the panoramic monitor, is essentially an elaboration of the ganging oscillator used for the alignment of broadcast receivers, the essential difference being that by drifting the oscillator of a conventional type of frequency changer the incoming carrier is caused to "scan" the receiver response curve. The oscillograms shown in Fig. 3 are typical of those obtained on the FM panoramic modulation monitor. As each sideband in turn "scans" the receiver response curve its image is reproduced, the height being a measure of the individual sideband amplitude.

FM and Television. — Reference has been made to the attempts of early radio engineers to reduce the bandwidth required by a broadcast station. The reason for their failure can now be discussed. The sidebands of a frequency-modulated carrier, as shown in Fig. 2, were calculated for the case of a steady sinusoidal 15 kc/s modulation. An amplitude-modulated transmission would require a band 30 kc/s wide to reproduce this modulation. Fig. 2 shows that however small the deviation this minimum bandwith will be required to pass the first pair of FM sidebands. If this bandwidth is reduced the modulation will be suppressed in exactly the same manner for either frequency modulation or amplitude modulation. Any attempt to reduce the receiver bandwidth so that it passes only, say, a 1 kc/s deviation, would automatically eliminate the sidebands produced by any modulation above this frequency. A receiver with a 2 kc/s pass band would in fact suppress all modulation frequencies greater than 1 kc/s.

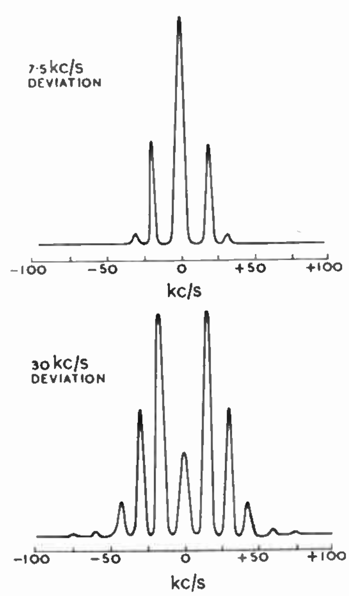

Fig. 3. Traces of oscillograph records of sidebands shown on the panoramic monitor. The modulation frequency is in each case 15 kc/s, and the similarity to the corresponding examples in Fig. 2 should be noted.

The latest American television stations have standardised on FM for their sound channel while adhering to amplitude modulation for the vision channel. This decision results partly from the fact that the basic advantages derived from FM are only realised when the deviation is one or more times the maximum modulation frequency. With a television channel handling a maximum modulation of some 3 Mc/s to 4 Mc/s, the bandwidth required by a single FM station, with a deviation ratio of two, would be some 12 Mc/s to 16 Mc/s. On the pre-war bands allocated to television, it would be impossible even to consider such an increase in the station frequency width. It therefore seems certain that if the advantages of FM are to be enjoyed by vision as well as sound, there will have to be a substantial increase in the frequency used for television transmission. There seems quite a good case for operating a post-war service on the 100 Mc/s or even the 200 Mc/s band.

APPENDIX

The equation developed by Roder for a frequency modulated wave is somewhat lengthy, as it includes a group of terms dealing with the amplitude of each sideband. In actual fact there is no end to this formula as there are an infinite number of sidebands. However, in practice, their amplitude falls off rapidly above and below the maximum and minimum deviation frequencies.

The sideband equation for a frequency modulated wave is :—

$$e = A\{J_0(m_p)\sin \omega t + J_1(m_p)[\sin(\omega + p)t - \sin(\omega - p)t] + J_2(m_p)[\sin(\omega + 2p)t + \sin(\omega - 2p)t] + J_3(m_p)[\sin(\omega + 3p)t - \sin(\omega - 3p)t] + \ldots \text{etc.}\}$$

Where

A = The amplitude of the unmodulated carrier.

$J_n(m_p)$ = Bessel functions of the first kind of order n, for the argument m_p.

$\omega = 2\pi f_c$ where f_c is the carrier frequency.

$m_p = F_d/F_m$ where F_d is the frequency deviation and F_m is the modulation frequency.

$p = 2\pi F_m$, t = time, e = voltage.

It will be seen that for any value of deviation ratio (m_p) chosen, that there is a carrier $[J_o(m_p)]$ and an infinite number of sidebands above and below the carrier $[J_1(m_p)$, $J_2(m_p)$, $J_3(m_p)$ . . . etc.], the amplitude of each of these values of $J_n(m_p)$ may be evaluated with the aid of a table of Bessel functions[3, 7]. In passing it may be mentioned that such tables present no more difficulty than a table of logarithms. The frequency separation between adjacent sidebands is equal to the audio-frequency (F_m).

The sideband amplitudes shown in Fig. 2 were calculated with the aid of the above formula. It is of interest to compare these results with those obtained on the panoramic monitor (Fig. 3).

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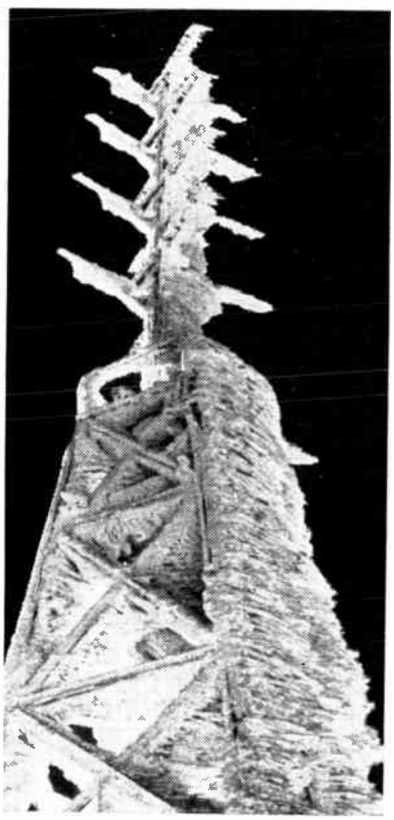


ICING is an enemy of transmitting aerials as well as of aircraft. This photograph shows a heavy deposit of ice on the 4-bay FM aerial at station W39B on the summit of Mt. Washington, Boston, U.S.A.

REPRODUCING RECORDS WITH LARGE RADIUS NEEDLES

IT has been generally accepted that a needle with a tip of as small radius as possible is desirable for optimum reproduction from lateral-cut gramophone records. This assumption has been based on the theory that the modulations are of equal lateral amplitude throughout the depth record groove, and it was therefore considered that a needle fitting tight to the bottom would penetrate the groove farthest, and so give the greatest high-frequency output.

In a recent paper* it is claimed that some unexpected benefits can be obtained from the use of a needle point of large radius which makes contact only with the upper side walls of the record grooves.

Graphical comparisons were made between three sizes of needle tip, 0.0023in., 0.00275in., and 0.004in., the bottom radius of the groove being 0.0022in., the width 0.006in., and the included angle 88 degrees. It was apparent that the greater area of contact was given by the smaller radius needle tip due to its close fitting in the bottom of the groove. But it must be recognised that the least irregularity or lack of symmetry in the groove shape would reduce the area of contact to even less than that of a 0.00275in. needle.

An enlarged plan view of part of a modulated record groove, with a 0.004in. needle inserted, was also presented. The modulations represented a sine wave of 7,000 c/s near the inside of a 78 r.p.m. standard record with a peak-to-peak amplitude of 0.0004in. It was obvious that the full amplitude could not be traced by a radius tip of such dimensions, and it would seem that an increased amplitude could be obtained by decreasing the needle radius, thus allowing it to drop into the groove.

In a curve showing the effect of tip radii, varying from 0.002in. to 0.006in. on the electrical output for a constant frequency of 5,000 c/s with 0.0002in. peak-to-peak amplitude, other factors being unchanged, the maximum output was reached with a tip radius around 0.004in.

This increase of high-frequency output results from the fact that HF modulations are not impressed in equal amplitudes throughout the depth of groove, and are less at the bottom, which can be attributed primarily to certain stages in the record manufacture. During processing, the grooves are distorted by the chromium plating, which deposits a heavier coating on the raised surface (corresponding to the groove bottom), and, in pressing, the raised portions (again equivalent to the groove bottom) become worn and distorted by the squeezing of the "biscuit" of record material across the surface.

Two records pressed from the same stamper were reproduced by the same turntable under identical conditions, except for the needle tip radius. An improved signal-to-noise ratio was obtained with the 0.004in. needle. Measurements made of the signal-to-noise ratio in the modulated groove show that a large radius needle tip still retains a superior signal-to-noise ratio at 500 playbacks. Other curves reveal that there is an appreciable reduction in surface-noise at 7,000 c/s with the wider needle, and that the tracking at 94 c/s is more accurate.

In these results Mr. Reid's research, if confirmed by other workers in this field, would seem to reside the explanation for tolerable quality record reproduction with fibre and other non-metallic needles, whose tips must of necessity broaden rapidly. D. W. A.

* "Large Radius Stylus for the Reproduction of Lateral Cut Phonograph Records," by John D. Reid. *Journ. Acous. Soc. Am.* Vol. 13. No. 3, Jan. 1942.

P.M.G. EXAMINATIONS

—and the Training of Marine Radio Officers

By WILLIAM M. MOORE

(Head of the Radio Dept., South Shields Marine School)

The author urges the need for higher standards of training and qualification for marine Wireless Officers, who it may be expected, will after the war be responsible for the operation and maintenance of much more complex and highly developed apparatus.

ONE of the effects of the war has been the definite lowering of the already comparatively low standard of technical knowledge required by candidates for the various Certificates of Proficiency in Radiotelegraphy issued by the Postmaster-General. A careful comparison between typical questions set for the pre-war 1st Class P.M.G. Certificate and those for Grade III for the City and Guilds of London Institute examination in Radio Communication will show clearly that the standard set for the former was relatively low.

Before the present war, three grades of certificate were issued on the results of examination:—

(a) Special Certificate.
(b) 2nd Class Certificate.
(c) 1st Class Certificate.

The telegraphy standard required for the Special and 2nd Class Certificates was 20 w.p.m. plain language; 16 w.p.m. code, and 10 w.p.m. figures. For the 1st Class Certificate the telegraphy standard is 25 w.p.m. P/L; 20 w.p.m. code and 12 w.p.m. figures. In all cases only negligible errors are allowed.

A candidate for the wartime Special Certificate undergoes a practical examination which includes:—

(a) Regulating and adjusting the sending and receiving apparatus;
(b) altering the wavelength;
(c) testing and charging accumulators;
(d) varying the transmitted power;
(e) tracing and clearing simple faults on the transmitter and receiver.

Further, he is verbally examined and is required "to *know the functions* of the various pieces of apparatus in the wireless installation used for the examination."

For the 2nd Class Certificate a candidate sits for a written examination, which consists of eight questions for which three hours are allowed. This is followed by a practical and verbal examination of a higher standard than that required for the Special Certificate.

The examination for the 1st Class Certificate consists of two papers; the first on electricity and magnetism, for which two hours are allowed; the second, similar to that for 2nd Class, on marine radio apparatus, for which three hours are allowed. In addition, there is a verbal and practical examination. The paper on electricity and magnetism which is set in the 1st Class examination is elementary and does not call for any mathematics worth mentioning.

The paper on marine installations which is set for both the 2nd Class and 1st Class examinations consists of questions of a descriptive nature.

Since the end of 1939 the ordinary examinations for 2nd Class and 1st Class Certificates have been suspended. Examinations for the Special Certificate are held at regular intervals at radio schools in various parts of the country. The average time taken by students to reach the standard for this examination is approximately five months.

After six months' service as a Junior Radio Officer the holder may sit for a modified examination for the 2nd Class Certificate. This examination consists of a written test of eight questions to be done in three hours. Candidates for this examination are not allowed time to attend a suitable course of instruction ashore and are expected to prepare for it in their spare time at sea.

Criticisms

The pre-war system of examination for P.M.G. Certificates is open to the following criticisms:—

(a) The technical standard is too low.

(b) Although the certificates are called Certificates of Proficiency, a candidate may sit for the 1st Class Certificate without having previously obtained a certificate of lower grade and does not have to prove actual experience as a Radio Officer.

(c) The written examination for the 2nd Class Certificate does not test the candidate's knowledge of electrical principles.

(d) The questions set on the papers on marine radio apparatus are of such a type that a system of cramming by memorising answers to standard questions is in common use among students. This is encouraged by the fact that it is possible before an examination to predict at least half the questions which will appear on the paper.

(e) The practical examination for both the 2nd Class and 1st Class Certificates does not emphasise sufficiently the use of testing instruments in tracing faults and circuits.

(f) The candidate's ability to carry out minor repairs and his familiarity with tools is not tested.

I suggest that the standards of the examination should be raised and that the system of examination should be amended as follows:—

A new applicant for a position as a Radio Officer should first undergo a course of training at an approved radio school and be allowed to sit for a 3rd Class Certificate, which would qualify him to serve as a Junior Radio Officer in any ship.

This examination to consist of:

(1) A written examination on electricity and magnetism.
(2) Practical and verbal examination such as is now set for the 2nd Class Certificate.
(3) Operating tests as now set for the 2nd Class Certificate.

After, say, 12 months' actual sea service the holder of a 3rd Class Certificate would be eligible to sit for a 2nd Class Certificate, the examination for which might consist of:—

(1) A written examination of three papers on electrotechnology, radiotechnology and marine type equipment.

(2) A practical and verbal test to prove the candidate's ability to operate and maintain a complete marine radio installation, including minor repairs.

(3) An operating test with telegraphy speed 25 w.p.m. P/L; 20 w.p.m. code.

The holder of this certificate to be qualified to act as Officer-in-Charge of Class 2 and Class 3 ships or as Second Radio Officer on Class 1 ships.

After a further period of sea service in one of the capacities laid down in the preceding paragraph the holder of a 2nd Class Certificate should be eligible to sit for a 1st Class Certificate. The examination for the 1st Class Certificate to be on similar lines to that laid down for 2nd Class Certificate, but a higher standard to be required and, in addition, the examination to include the type of apparatus used mainly on very large passenger ships. The holder of this certificate would be qualified to act as Officer in Charge of Class 1 ships.

Candidates for the 1st Class and 2nd Class Certificates should be allowed to sit for an additional receiving test, using a typewriter, and if successful their certificates to be suitably endorsed.

The examinations for 1st Class and 2nd Class Certificates should be divided into two distinct parts: A, operating and procedure; B, technical. In the event of a candidate failing in one part of the examination and obtaining a satisfactory pass in the other part, he should be credited with this pass and at the next examination take only that part in which he failed.

Training Courses

Naturally, the training of Radio Officers is determined by the examinations for which they will have to sit. In the past, training courses have been planned to enable students to pass the examination in the shortest possible time. In other words, a course of instruction designed to produce efficient operators with a thorough understanding of their profession is not the same as one designed to get a student through the examination, especially when the employment of cramming can produce satisfactory passes. The result is that in the past large numbers of Radio Officers have qualified for P.M.G. Certificates without the background of a thorough knowledge of the principles of electricity and radio which is so necessary.

Training courses could be arranged to start with instruction in electrical principles on the lines already approved by the Institution of Electrical Engineers for the evening technical courses for the National Certificates in Electrical Engineering. Particular emphasis should be laid on the types of circuits and machines used in radio practice. In addition to lectures, as much laboratory work as possible should be included. The succeeding course of instruction in radio theory should be arranged so that a large amount of the work can be done in the laboratory.

Experiments demonstrating such things as static and dynamic characteristics of diodes, triodes, tetrodes and pentodes; resonance in AC circuits; production of oscillations, valve oscillators; modulation; rectification of AF and RF currents can be easily arranged and will prove a valuable form of instruction. Students should build up their own circuits and wind the necessary coils.

The equipment in the radio laboratory should include cathode-ray oscilloscopes, signal generators, voltmeters, ammeters, milliammeters, power packs, potentiometers, valves and batteries, as well as components such as transformers, chokes, condensers and resistances. Students should be given workshop practice and instructed in the use of tools.

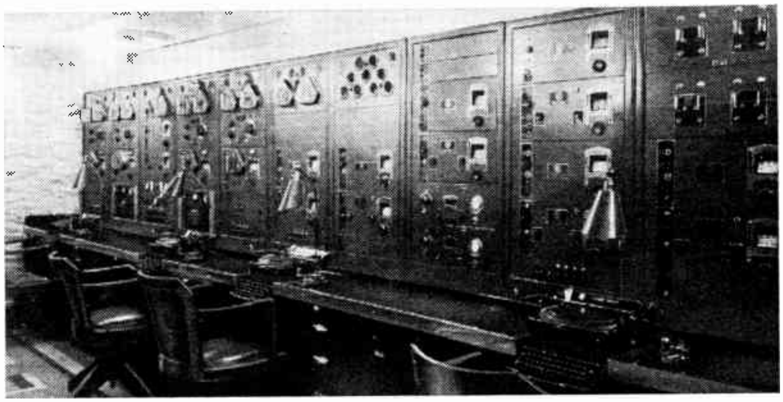
The courses of instruction should be approved by the examining body, which should exercise the right to inspect approved schools to ensure that the syllabus is being adhered to and that the instruction given is satisfactory.

It is inevitable that the scheme of training and examinations which I have outlined will meet with a great deal of criticism from all who are directly interested. Much discussion will be necessary, and many conflicting interests will have to be reconciled before such a scheme can be adopted. The only satisfactory and workable arrangement will be one which has the goodwill and approval of the Radio Officers themselves, the employers and the Post Office, as the examining body.

Technical Standards

On one point, however, there will, I think, be general agreement, and that is the necessity of a sustained increase in the standards of training and examinations. The technical standard required and reached by officers of both the navigation and engineering departments of the Merchant Navy is very high. The highest certificates in each department, that of Extra Master and Extra Chief Engineer, are classed as the equivalent of a B.Sc. degree.

By comparison, the standard of the P.M.G. examinations is very low indeed, and this is amply illustrated by the fact that a student of average intelligence with a good elementary education can pass the examination for the 1st Class P.M.G. certificate after eighteen months' attendance at a radio school. An engineer, on the other hand, serves four years' apprenticeship ashore, during which time he attends organised courses at evening classes or a sandwich course at a technical school. He must then serve eighteen months as a junior engineer before being



Receiving apparatus and transmitter control gear of the liner *Queen Mary*. After the war, marine installations may be expected to become even more complex.

P.M.G. Examinations—
eligible to sit for a 2nd Class Engineer's Certificate and a further eighteen months before sitting for a 1st Class Certificate. For each of these certificates a period of several months' attendance at a suitable school is necessary, and in addition very many engineers take correspondence courses of study while at sea. A long period of study is necessary to reach the standard for the Extra Certificate, and only a small proportion of engineers obtain it.

Complicated Equipment

The radio department on Merchant Navy ships is bound to grow in importance as each year brings further developments. Equipment will, with improved design and wider scope, tend to become more complicated. New ideas in DF apparatus together with, probably, some applications of radiolocation are likely. Any improvement in the standard of technical training and examinations will raise the efficiency of the radio department of the Merchant Navy, and this will be to the benefit of the whole Service.

Radio officers did a good job of work before the war, often under great difficulties with obsolescent equipment. They are doing a grand job now, for which all honour is due to them. Their unceasing efforts to improve their efficiency and the standing and status of their chosen profession is worthy of complete success. It is their just due that they should be given the opportunity of a comprehensive course of training and a certificate which, while not easy to obtain, will bear comparison with that of their fellow officers.

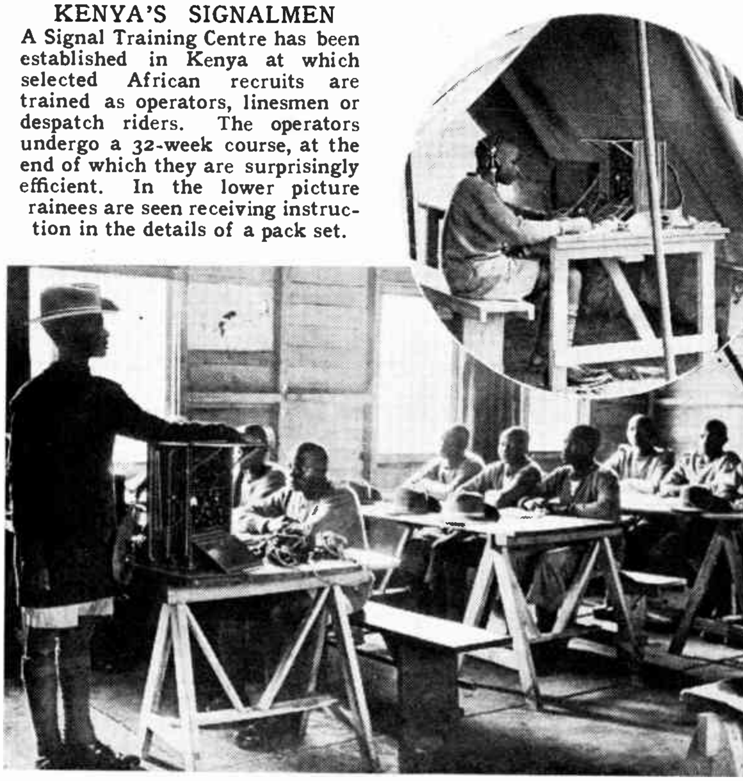
"KEEP IT GOING!"

MAINTENANCE of civil broadcast reception has now become a pressing problem, and the appearance of this booklet, issued by Murphy Radio, could hardly have been more opportune. One is inclined at first to question whether it is wise to encourage the layman to delve into the vitals of his receiver, but any unworthy doubts on this score are dispelled on reading the contents. Nowhere is the reader encouraged to do anything that is likely to do more harm than good; all the advice given to him is admirable, and is clearly written from a deep knowledge of the way in which the public is inclined to use—or misuse—its receivers.

The function of "Keep it Going!" is to show the owner of any set—not only a Murphy set—how to do everything in his power, in the absence of professional help, to keep his set working in wartime. The booklet, which costs 6d., is distributed through Murphy dealers, but in cases of difficulty copies are obtainable direct from Murphy Radio, Ltd., Welwyn Garden City, Herts.

KENYA'S SIGNALMEN

A Signal Training Centre has been established in Kenya at which selected African recruits are trained as operators, linesmen or despatch riders. The operators undergo a 32-week course, at the end of which they are surprisingly efficient. In the lower picture rainees are seen receiving instruction in the details of a pack set.



BOOKS RECEIVED

Radio Engineering. By Roy C. Norris. Written for those with little previous knowledge who wish to learn about radio. Treatment is practical and expository rather than theoretical, and the scope is very wide, including such aspects as wave propagation, receiving, transmitting, television, servicing, interference suppression and many other subjects. Marine and aviation radio and even wireless manufacturing methods are dealt with. Pp. 512; over 600 illustrations. Published by Odhams Press, Ltd., Long Acre, London, W.C.2. Price 6s. 6d.

Marine Radio Operator's Guide. By H. E. Chamberlain. Information for the newly joined marine Wireless Officer; shipboard life, uniform and kit required, status and etiquette. Though not a technical book, the beginner's normal training is supplemented by information on such matters as direction finding, maintenance of apparatus and short-wave working. Chapters on watch-keeping and various aspects of operating are included. Pp. 72; 4 illustrations. Published by Hutchinson and Company, 47, Princes Gate, London, S.W.7. Price 5s.

Whereas I was Blind. By Ian Fraser. This is not a wireless book, but wireless men will read with great interest the account of how Sir Ian Fraser overcame his disability of blindness. The author has long been associated with various aspects of wireless, and the book discloses some little-known facts about the initiation of the "talking book" scheme, for which electrical reproduction is, of course, employed; few developments have given more comfort to the blind, especially to those who have become blind in later life. A chapter is devoted to Sir Ian's work for the B.B.C. Pp. 169, with portrait of the author. Published by Hodder and Stoughton, Ltd., Warwick Square, London, E.C.4. Price 8s. 6d. net.

Aircraft Radio. By D. Hay Surgeoner. This revised 2nd edition begins with information on the international control and organisation of civil aviation radio services. This is followed by chapters on direction finding, blind-landing systems and aircraft equipment and its operation. Complementary airport equipment (including lighting systems) is also dealt with. Pp. 154; many photographic illustrations, explanatory drawings and circuit diagrams. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 15s.

HIGH-SENSITIVITY DC AMPLIFIER

Another Application of the CR Tuning Indicator

By

GEORGE A. HAY, B.Sc.

IN view of the interest which has been aroused in biological circles in the original design for a DC amplifier embodying a "Magic Eye" tuning indicator (*Wireless World*, March, 1942, p. 63), it has been thought desirable to add a few notes on the more complicated arrangement mentioned in that article, which gives a sensitivity increase of over one hundred times.

It will be recalled that the maximum possible increase in sensitivity with the simple arrangement was some ten times; if attempts are made to increase this, instability results. A much greater increase is possible, however, by making use of an extra valve. Fig. 1 shows the skeleton circuit of a simple DC valve bridge. R2 is the DC resistance of the triode, and when R1/R2 = R3/R4 the output to the detector will be zero, i.e., the bridge is balanced. R2, however, can be varied by changing the DC input to the valve, hence any such variation in input is indicated by a corresponding but much greater change in the bridge output. Using a valve such as the Mazda AC2HL with $\mu = 75$, a voltage gain of fifty times is easily obtainable.

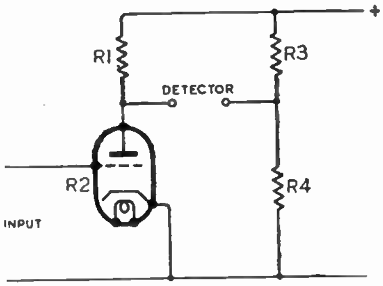


Fig. 1.—Basic circuit of the valve bridge used as a DC amplifier.

If we use a CR tuning indicator as the bridge detector, a change of 100 mV is easily visible—hence the minimum visible change in input is about 2 mV. This is very little better than the original simple form of indicator previously described. If, however, we replace R3, or part of it, by the target-cathode resistance of the "Magic Eye" itself, it will be found that the phase relations are correct for positive feed-back to take place with a resulting increase in sensitivity. It might be thought a more obvious solution to include a cathode resistor, as in the original design, but this gives rise to a circuit which is much less convenient practically. The ultimate results of the two circuits are precisely similar.

As in the original design, the above arrangement gave unmanageable sensitivity accompanied by instability and backlash, and in practice it is necessary to shunt the CR indicator with another resistance to reduce the amount of feed-back. A suitable practical circuit is shown in Fig. 2, which is designed round the Mullard EM1. Other tuning indicators are not so successful on account of rather larger target currents. The amplifier used was a Mazda AC2HL, and, while this gave satisfactory results, if a very high input impedance is required, it might be advisable to use a top-grid valve such as a Mazda SP41 or Osram KTZ41, triode-connected. It can be shown that the maximum voltage change is obtained when R1 = R2, but in practice it is better to make R1 = 3R2 in order to get sufficient target voltage for the EM1.

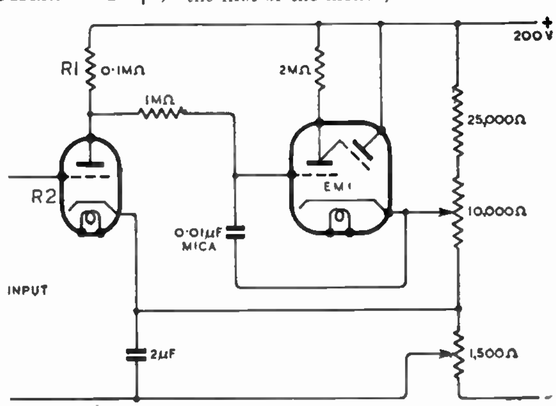


Fig. 2.—A practical version of Fig. 1, embodying a CR tuning indicator.

In operating the amplifier, the initial grid bias of the triode is first set by adjusting the 1,500Ω resistor to a value sufficient to avoid grid current. (A value of about 1.2 volts is suitable, and it helps matters to run the cathode at a lower temperature than normal.) The 10,000Ω resistor is then adjusted by trial and error to give the correct amount of feed-back, and the bias potentiometer finally set for zero reading. Owing to the increased complexity of the circuit, precise values cannot be given, as in the case of the simple arrangement, and a certain amount of experimenting with resistance values might be necessary to suit individual valves. It is helpful in this connection to note that the smaller the resistance shunted across the EM1, the less sensitive is the circuit. If very high sensitivity is required, it would be advisable to stabilise both the high-tension and heater supplies to avoid zero drift. The maximum sensitivity obtained with this arrangement with complete stability has been about 0.2 mV for an easily visible movement of the shadow; if a less stable arrangement can be tolerated, this is easily increased to 0.1 mV or even less.

Abstracts and References

THE subject and author indexes to the abstracts and references published in our sister journal, *Wireless Engineer*, during 1942, will again be issued as a separate publication early in 1943. It is understood that supplies will be limited and it will, therefore, be necessary to make early application to our Publishers. A charge of 2s. 8d. (including postage) will be made. The December issue, which was on sale on the first of the month, includes the index to the original articles published in Volume XIX, 1942, and to the authors. Issues are obtainable to order through newsagents, or direct from Publishers at 2s. 8d., including postage.

RADIO DATA CHARTS

By

J. McG. SOWERBY,

B.A., Grad. I.E.E.

(By Permission of the Ministry of Supply)

No. 3 (3rd Series)—*The Characteristic Impedance of Transmission Lines*

WITH the growing use of higher and higher frequencies, the transmission line—especially the co-axial type—has become of considerable importance to the radio experimenter and designer. Besides their normal function of transmitting radio frequency energy from point to point as required, lines are being used more and more to replace " lumped" circuit elements which become increasingly difficult to construct as frequencies rise.

Perhaps the most important constant of a transmission line is its characteristic impedance. In passing, it is worth noting that this constant is sometimes referred to as the " surge impedance " and the " iterative impedance " by various authorities, but " characteristic impedance " is more usual. The abac sets out to calculate this constant from geometrical dimensions for six different line configurations. The inductance and capacitance per unit length are useful design data and so are included.

The characteristic impedance of a line is defined as the input impedance of a line of the same geometrical dimensions of infinite length. In any real line, whether of infinite length or not, there must necessarily be conductance and capacitance between the " go " and " return " leads, and inductance and resistance in both, even though their numerical value may be small. It is this fact which causes any line to have an input impedance to AC, and it can be shown (see for instance Everitt's " Communication Engineering," 2nd Ed., Chap. 4.) that the input impedance of an infinite line when the capacity, etc., is uniformly distributed along the line is given by :—

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

Where R = resistance per unit length
L = inductance per unit length
G = conductance per unit length
C = capacitance per unit length

Fortunately, when dealing with radio frequencies, ω is large, and ωL becomes large compared with R, and ωC becomes large compared with G. To a close approximation, therefore, we may write

$$Z_0 = \sqrt{\frac{j\omega L}{j\omega C}} = \sqrt{\frac{L}{C}}$$

and this is the relation on which the chart is based.

This assumption of high working frequency which has been made in the case of the characteristic impedance, has also been made in the calculation of the inductance and capacitance scales of the abac. Actually, the assumption comes up in slightly different form, and is that the velocity of transmission is that of light. In addition it is assumed that the distance between the conductors (D) is large compared with their diameter (d). At usual frequencies these assumptions are not very serious ; and Hund (" Phenomena in H.F. Systems," 1st Ed., p. 449) gives the deviation of the transmission velocity from that of light at different frequencies for a typical two-wire line of characteristic impedance 490 ohms. At 16Mc/s the deviation is 0·139 per cent., and at 34Mc/s is 0·095 per cent. At higher frequencies the deviation becomes progressively less. Similar figures are obtained for other line configurations.

For reference purposes the line configurations and the appropriate formulae are given in Table 1.

The Use of the Abac

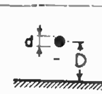
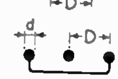
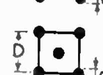
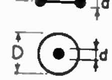
For each type of line configuration, a curve appears on the abac and is used when finding the characteristic impedance of that configuration from its geometry. The capacitance and inductance scales are independent of these curves and are related only to the characteristic impedance scale. A worked example will make this clear.

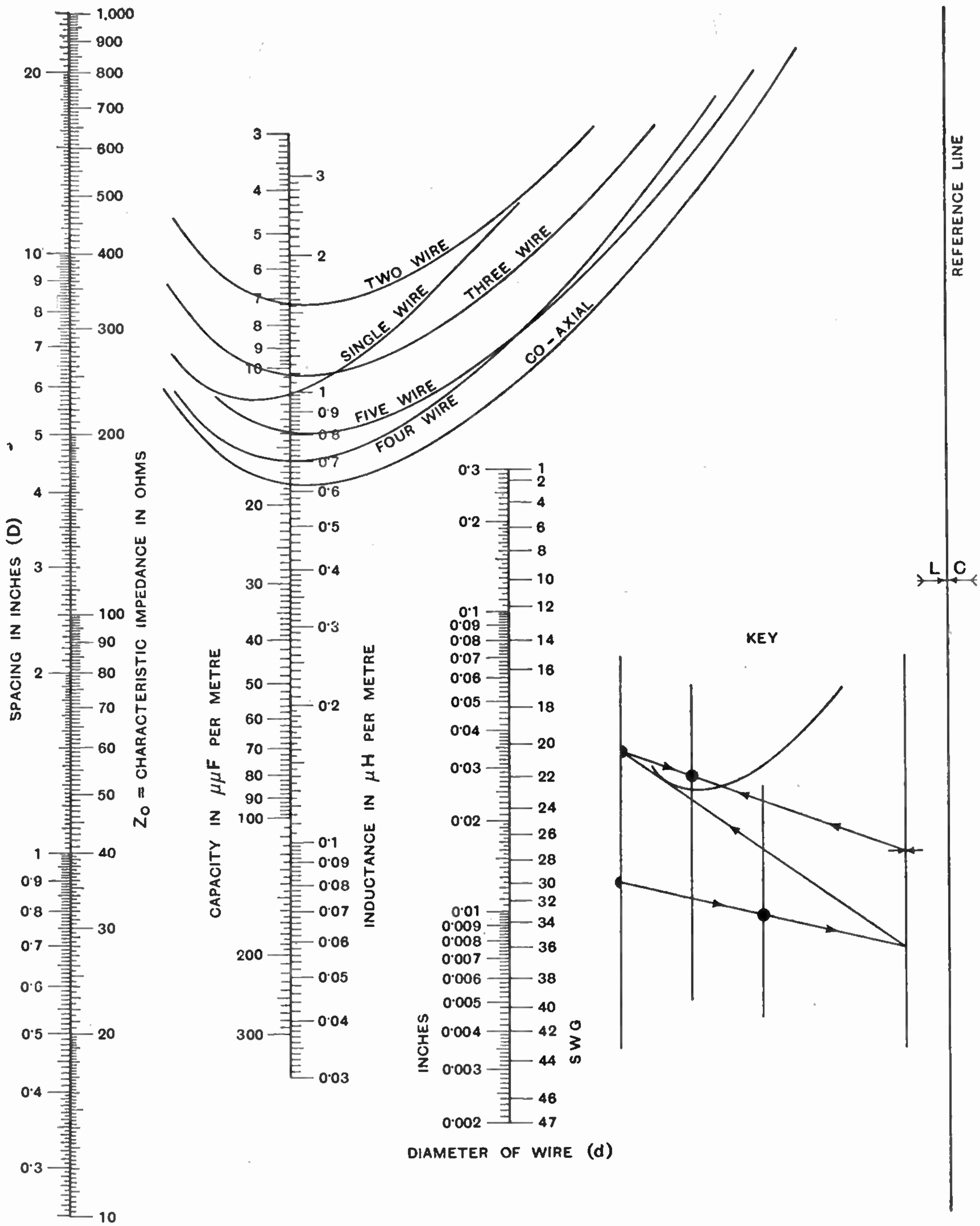
Example 1.—It is proposed to match an aerial to a receiver by means of a two-wire line consisting of two 16 SWG wires ten inches apart. What is the characteristic impedance ? Set the ruler on 10 on the D scale and 16 SWG on the d scale. A point of intersection is found on the reference line. From this point draw a tangent to the two-wire curve and the characteristic impedance is read off the Z_0 Scale. It is 689 ohms. What now is the capacitance per metre of this line ? Set the ruler on 689 on the Z_0 scale and on the gauge point LC on the reference line. The ruler cuts the capacitance scale at 4·835 $\mu\mu$F per metre, the answer required.

Like most abacs, this one may be used backwards, and this is

(*Concluded at foot of Col. 1, page 12*).

TABLE I.

Line Configuration	Description.	Formula for Characteristic Impedance at RF (Z_0).
	Single Wire	$Z_0 = 138 \log_{10} \frac{4D}{d}$
	Two Wire	$Z_0 = 276 \log_{10} \frac{2D}{d}$
	Three Wire	$Z_0 = 207.3 \log_{10} \frac{\sqrt[3]{4}D}{d}$
	Four Wire	$Z_0 = 138 \log_{10} \frac{\sqrt{2}D}{d}$
	Five Wire	$Z_0 = 172.5 \log_{10} \frac{\sqrt[4]{2}D}{d}$
	Co-axial	$Z_0 = 138 \log_{10} \frac{D}{d}$



CHARACTERISTIC IMPEDANCE OF TRANSMISSION LINES

Wireless World Brains Trust

Does Clerk Maxwell "Date"?

Control of Amateur Transmitters

Question No. 8.—How is Clerk Maxwell's Electromagnetic Theory affected by modern conceptions of the nature of electricity and the absence of the ether as a medium of propagation?

J. C. JEVONS.

Professor G. W. O. HOWE, D.Sc., M.I.E.E., Technical Editor of our associated journal, "Wireless Engineer," replies:—

THE answer to this question depends very largely upon what you understand by Clerk Maxwell's Electromagnetic Theory. Hertz wrote: "Maxwell's theory is Maxwell's system of equations. . . . Maxwell arrived at them by starting with the idea of action-at-a-distance and attributing to the ether the properties of a highly polarisable dielectric medium. We can also arrive at them in other ways. But in no way can a direct proof of these equations be deduced from experience. It appears most logical, therefore, to regard them independently of the way in which they have been arrived at, to consider them as hypothetical assumptions, and to let their probability depend upon the very large number of natural laws which they embrace."

Again, E. Cunningham writes in Pearson's *Grammar of Science*: "The true function of the ether is merely to assist the mind to a clearer understanding of the sequences of these phenomena. Nothing more is to be predicated of it than the laws that express concisely how these sequences are unfolded. The ether of the electromagnetic theory is to the scientist now nothing more than a vague substratum whose only properties are specified by a number of mathematical equations which will always be associated with the name of Clerk Maxwell."

It will be seen from these two quotationse that the ether forms no essential part of Maxwell's theory. It was introduced because it was felt at the time that the phenomena represented by the equations necessitated space being endued with properties which could not be the properties of mere nothingness, and the mind, therefore, filled empty space with this fictitious medium and endued it with all the necessary properties. If one is prepared to endue empty space with the properties necessary to give a working picture of electromagnetic phenomena, and thus make the equations something more than mere mathematical symbols, there is obviously no need to postulate an all-pervading ether. There has been a tendency in recent years to endue empty space with properties which a few years ago would have been regarded as inconceivable—and still are by many people. For example, we are told that a gravitational field acting on empty space endues it with curvature. No harm is done by referring to empty space as the ether so long as one does not go further and begin to ask meaningless questions about it.

When an alternating current of high frequency flows in an aerial it loses energy, which reappears after a very short time in a distant aerial. During the interval the energy was undoubtedly traversing the space between the transmitter and the receiver. In what form was the energy? It is not very satisfying to be told that it was in the form of some differential equations, although there are those who maintain that this is the limit of our knowledge of the matter. If one believes that the space between two oppositely charged conductors in a vacuum is in a peculiar state known as an electric field, and the space around a current-carrying conductor in a vacuum also in a peculiar but different state known as a magnetic field, and that each field represents an amount of energy, then one will have no difficulty in picturing the electromagnetic wave travelling from the transmitter to the receiver.

It is doubtful whether modern views of the nature of electricity are in any way antagonistic to Clerk Maxwell's electromagnetic theory.

In his book *The A.B.C. of Relativity* Bertrand Russell says: "Throughout all the revolutions which physics has undergone in the last fifty years, these equations (of Maxwell) have remained standing. Indeed, they have continually grown in importance as well as in certainty, for Maxwell's arguments in their favour were so shaky that the correctness of his results must almost be ascribed to intuition." That was written in 1925, but it stands to-day. In his *Electromagnetics* (1938) O'Rahilly says: "We have no difficulty in deciding that the hypothesis of an 'aether,' whatever it is supposed to mean, does not nowadays pertain to the science of physics; for its denial does not make any alteration in any formula."

More views on Question No 6.

(Would not the control of all wireless matters be better vested in some independent body, like the F.C.C. in U.S.A., rather than in the G.P.O.?)

"T.J.R.," questions the accuracy of the querist's premises. He writes:—

DOES the G.P.O. really control *all* radio matters? It may do so nominally, but its control is rather indirect in the case of, say, broadcasting. Though all listeners have heard of "strong men" at

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RADIO DATA CHARTS

(Concluded from page 10)

brought out in the second example.

Example 2.—It is proposed to make a five-wire line of characteristic impedance 300 ohms from 14 SWG wire. What is the requisite spacing? Set the ruler on 300 on the impedance scale and draw a tangent to the five-wire curve. Join the point of intersection on the reference line to 14 SWG on the d scale, and the ruler cuts the D scale at 3.83 inches.

In the majority of cases the pattern of example 2 will be followed, since what is usually required is a line to match a given piece of apparatus. Matching is said to take place when a line is terminated with an impedance equal to its own characteristic impedance. Matching is important, because under these conditions no reflections are set up in the line, and the losses in it are at a minimum.

Broadcasting House, few are aware that the P.M.G. is its real overlord.

Again, why should the G.P.O. be any less "independent" than a body like the American F.C.C.? The G.P.O. certainly has interests in telecommunication other than in its capacity as a controlling body, but has no vested interests of a material character, in the sense normally understood. The profits of the G.P.O. go into the coffers of the State, and not to individuals.

Unless one feels that the G.P.O. is unsuited for the job by inherent incapacity for progressive thought, it is just as well for the Government to effect control of radio through it as through some new and untried body. To sum up, what matters here, as in all technical matters of social importance, is that the State should be imbued with a progressive democratic spirit that can be passed on to its executive departments.

A. D. GAY, President of the Radio Society of Great Britain, replies from the point of view of amateur transmitters, whose numbers may be expected to grow greatly after the war:—

WITH the G.P.O. monopoly of wireless communication (and, in fact, of all forms of electrical communication) it seems obvious that the issue of wireless licences must be under its control. Any other body, were it given the powers to grant licences to experimenters, would have to consult the G.P.O. on questions of powers and frequencies and conform to any regulations which may be made at International Conventions from time to time.

It would thus seem that to create an independent body such as the Federal Communications Commission would merely duplicate a department which already exists within the G.P.O. Whether such action would bring about more favourable consideration of requests for licences is exceedingly doubtful. The present Act of Parliament assures that anyone should have a transmitting licence who desires to carry out experiments, provided a certain elementary knowledge of radio is displayed by the applicant.

In the U.S.A. licences are granted to anyone, and for such purposes as third-party message handling. The size of the American continent and the absence of State monopoly over communications facilitates the unrestricted issue of licences. American amateurs have done valuable work in emergencies, bridging broken communications with portable radio equipment. In this country such assistance by amateurs might cause a loss of revenue to the G.P.O. and has never been encouraged.

The administration of radio matters in America is therefore a much wider and more democratic affair. In the absence of a State department dealing wholly with communications, the F.C.C. is, therefore, necessary, and fulfils the duties of administration in a less biased manner.

The system in this country could be improved by the invitation of amateur representatives to attend all committee meetings at which amateur activities are to be discussed. A great deal of useful and friendly co-operation exists, for example, the invitation of an amateur representative to attend International Conferences abroad. This amicable state of affairs might be improved at home.

A Demonstration Multivibrator

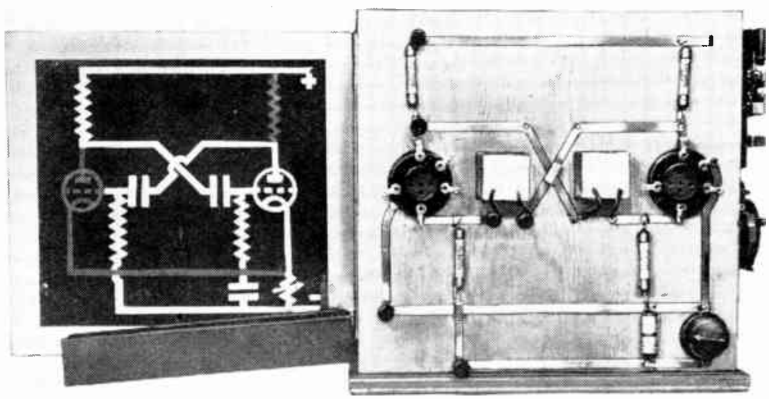
By E. WILKINSON, Ph.D.

THE apparatus shown in the photograph was developed in Loughborough College to assist students in understanding the working of the multivibrator. It portrays the electrical processes which are taking place in an actual circuit at a speed slow enough to be appreciated.

The circuit is a normal symmetrical multivibrator except for the two grid condensers, which are enormous compared with ordinary standards. Each is an electrolytic condenser of 16μF capacity, controlling the oscillation frequency down to one cycle in about three seconds. The layout of components on the breadboard back brings them into positions corresponding to the circuit diagram which is drawn out on a ground-glass screen. This forms the front face of the instrument, and the rest of the glass is blacked so that individual parts of the diagram may be illuminated from behind.

The operation of the multivibrator depends upon the periodical charge and discharge of the two condensers. This is demonstrated by each condenser circuit automatically lighting up blue when charging and red when discharging.

The lamps illuminating the diagram are switched on and off by a mercury-vapour relay, contained in the main body of the apparatus, and controlled directly by the grid potential of one of the multivibrator valves. The lamps illuminating the charge path of condenser 1 and the discharge path of



Front view of demonstration multivibrator showing components mounted in the positions they occupy in the conventional circuit. The ground glass screen is painted black leaving the circuit diagram transparent so that the charge and discharge conditions may be indicated by pilot lamps of different colour. Gas-filled relays and auxiliary circuits for the automatic control of illumination are mounted inside the case and circuit values are chosen to give a complete cycle every three seconds.

A Demonstration Multivibrator—

condenser 2 are fed in parallel from a low-voltage winding on a mains transformer. The lamps in the discharge path of condenser 1 and the charge path of condenser 2 are fed in series with a ballast resistance and the primary of this transformer. The function of the gas-filled relay is to short a high-voltage secondary winding, thereby cutting out the parallel lamps and throwing the mains supply almost entirely across the series lamps and the ballast resistance. The increased primary current is then sufficient to light the series lamps.

The working of the triggered multivibrator may also be demonstrated. Free running is stopped by increasing the bias resistance and cutting off valve 1. The cover plate, seen in the photograph below the diagram, hides the lower part of the diagram when the circuit is running free. This is now removed to show the modification in the circuit. Condenser 1 discharges and remains discharged, while condenser 2 becomes charged. This condition appertains until the application of a triggering pulse overcomes the bias and allows a single change over of the illuminated and darkened parts of the circuit.

RANDOM RADIATIONS

By "DIALLIST"

Licence Defaulters

JUDGING by the reports that one sees in the various daily papers the number of set users who don't take out receiving licences has reached an alarming total. One reads estimates of from 1,000 to 10,000 in some of the country's larger towns and the total for Great Britain and Northern Ireland may well run to a million or more. Evasion on this scale is a very serious affair, for it means that the B.B.C. is losing a large proportion of its just revenue at a time when it ought to be putting by a useful nest-egg for post-war repairs, reconstruction and expansion. I've always thought and I still think that one should have to produce one's receiving licence when buying a set or a replacement part. There wouldn't be any "hardship" about this, and it would certainly reduce licence evasion to a minimum, if it didn't end it altogether.

Frequencies and Wavelengths

EVERY reader must have been interested by the Editorial on "Classification of Frequencies" in last month's *Wireless World*. The present position is chaotic, to say the least of it. You may, for example, in one and the same article describing a receiving set find that the term "high frequencies" is used (a) for frequencies above about 4,000 c/s ("this circuit is designed to avoid attenuation of the high frequencies in the AF stages"); (b) for those between 300 and 150 kc/s (in describing the performance of the signal-frequency stages of a superhet in the long-wave band); (c) for those between 1,500 and 500 kc/s (signal-frequency stages in the medium-wave band); (d) for those between 20,000 and 3,000 kc/s (signal frequencies in the short-wave bands). "Intermediate frequency" may also be used in one or two paragraphs to describe a frequency which would elsewhere in the article be called high. And it's not too easy for the beginner when he comes to wavelengths. His friends who are short-wave enthusiasts probably call the bands between 10 and 100 metres the short waves and those below 10 metres the ultra-shorts. But he may find that the wavechange indicator of his so-called all-wave set shows the bands between about 30 and 80 metres as short and those between 15 and 30 metres as ultra-short. Coming back to frequencies, if the aforesaid beginner at radio owns one of those devices for sunshine treatment in the home, he may be perplexed by the discovery that the book of the words refers to its infra-red radiation as low-frequency and its ultra-violet as high.

Simplification Needed

A considerable straightening out is clearly needed, and here's one way in which a beginning could be made. I do feel pretty strongly that all of us who write on wireless or argue about it amongst ourselves should eschew once and for all such expressions as "high frequency" and "low frequency" stages in a receiver, with their corresponding abbreviations "HF" and "LF." What the aerial delivers to the grid of the first valve should always be called the "signal frequency" or SF, and the frequencies dealt with by the post-detector stages and the loudspeaker should be "audio" or AF. The latter are easily and comprehensibly divided up into upper, middle and lower audio frequencies—UAF, MAF and LAF. That leaves what we now call the "intermediate frequency" to be dealt with. Is any change needed here? I'm not sure that it is, for there doesn't seem to be much chance of confusion, at any rate when speaking of a superhet, if we refer to its departments as SF, IF and AF. If, though, a change is thought to be desirable in the interests of perfect clarity, we might possibly use "conversion frequency" (CF) instead of IF. I'm sure that the adoption of the nomenclature suggested for the working frequencies of the wireless receiving set would do a great deal towards smoothing the path of the beginner.

Can We Think in Frequencies?

But that is a very long way from being the whole of the story. We are still left with the classification of the whole vast range of electro-magnetic radiation frequencies, or at all events with that part of the spectrum with which wireless is concerned. There are those who claim that the problem would lose much of its difficulty if only we could bring ourselves to think in frequencies. But can we? Like most DX enthusiasts, I think of station frequencies rather than wavelengths and make my calibration charts in kilocycles or megacycles. In circuit-designing one must think and work in frequencies. But we can't go on doing so when it comes to short-wave aerials, transmission lines, and so on, for there we are concerned with the physical lengths of the waves with which they have to deal. Their heights, lengths and spacings have to be worked out in terms of wavelengths so that we can measure off in metres and centimetres or in feet and inches. Hence, thinking in frequencies, helpful though it is in many ways, is not a panacea for all one's wireless headaches.

What is Your Choice?

Each of the two systems given in the *Wireless World* Editorial has a good deal to recommend it—just as each has its drawbacks. I have a feeling that a kind of combination of the two might answer well. Here's what I'm driving at. Once you've got hold of such rather unfamiliar terms as myriametre, hectometre and dekametre (not so difficult if you remember that in the metric system multiplying prefixes are always Greek numericals and dividing prefixes are Latin), the order in which the wavebands come in the classification should stick in your head. Now, in the frequency side all that we have to do is to take the upper limit for each band. Thus, the myriametre waveband is concerned with tens of thousands of metres and the corresponding frequency range is below 3×10^1; it is thus frequency band No. 1. At the other end of the scale the centimetre waveband is concerned with hundredths of a metre and the frequency range corresponding is 3×10^7, so that it is a frequency band No. 7. Hence the table can become:—

Band	f in kc/s	Waveband name.	λ in metres
1	below 3×10^1 ...	Myriametre	above 10,000
2	$3 \times 10^1 - 3 \times 10^2$	Kilometre	10,000–1,000
3	$3 \times 10^2 - 3 \times 10^3$	Hectometre	1,000–100
4	$3 \times 10^3 - 3 \times 10^4$	Dekametre	100–10
5	$3 \times 10^4 - 3 \times 10^5$	Metre	10–1
6	$3 \times 10^5 - 3 \times 10^6$	Decimetre	1–0.1
7	$3 \times 10^6 - 3 \times 10^7$	Centimetre	0.1–0.01

What do you think of the suggestion? I think there's something in it; possibly you can suggest something simpler and better.

To Jam or Not to Jam?

THOUGH the Axis Powers do their level best to jam as many as possible of the news and talks broadcasts put out by ourselves, the Americans, the Russians and other Allied peoples, the B.B.C. seldom, if ever, retaliates. Russia appears to indulge in a certain amount of interference with German and Italian transmissions. I don't know what the Americans are doing, but I don't fancy that they are bothering much to spoil reception by their people of the stuff dished out by Goebbels, Gayda and others of the gang. I saw it reported the other day in one of the lay papers that a B.B.C. official when asked "Why don't you jam Germany and Italy?" replied, "Why should we?" Personally, I take rather the same view. Hitler and Musso have such a wealth of broadcasting stations at their disposal in their own and in occupied countries that they can well afford to use a good many of them as jammers if they feel so minded. But we need all the long, medium and short wavelength transmissions that can be spared to give news to the Empire as well as to foreign countries. In any event, jamming, no matter how heavily it's done, is never a hundred per cent. effective; even when it is combined with terrific penalties for listening to the B.B.C. it does not prevent our news from reaching the people we want it to reach.

Those American Valves

IT seems to take a long while for those American valves which the Board of Trade agreed should be released for replacement purposes in broadcast receiving sets to find their way into the shops. It's a good while since their coming was announced, but there seem to be few of them about yet. Perhaps their distribution will have been speeded up by the time that these lines are in print, and readers whose sets have been silent for want of the necessary "toobs" will once more be able to listen to news and entertainment. Far too many sets are out of action either because spares are unobtainable or because service men can't cope with the work thrown upon their depleted ranks.

Bits and Pieces

Meantime, I've seen some weird sets put together out of the quaintest museum pieces in the way of components, retrieved from the obscurity of junk box or attic. Old straight-line-capacity variable condensers, worked by the kind of slow-motion dial that one hasn't seen for ten years or more, are yoked to tuning coils of the kinds that were illustrated in the advertisement pages of *Wireless World* in the late '20's or early '30's. Fixed condensers, resistances, transformers and switches of almost forgotten makes and types have been resurrected and are doing good service. One set was actually tuned by a variometer of about 1923 vintage. Another had a couple of those big flat variable condensers with mica dielectric that used to be made by the Polar people. I am still hoping to find a vario-coupler dug out from the depths and given a new lease of life. Under the conditions of to-day, when the set need only bring in a couple of medium-wave stations and requires no long-wave band, quite passable reception can be obtained with components that we wouldn't have thought worth bothering about in 1939. One thing is that, thanks to our network of high-powered broadcasting stations, a simple three-valve straight receiver will normally provide adequate reception: at any rate it enables the news bulletins to be heard almost anywhere in the country. The quality may leave a good deal to be desired, but in wartime almost any kind of set is better than none at all.

Woomph!

CAN anyone explain why it is that those who use receiving sets for bringing in the dance music of the day so often find it desirable to turn the tone control as far counter-clockwise as it will go, or very nearly so? Is it because this takes the edge off the excruciating noises produced by muted trumpets and other strange instruments, thereby rendering them less unbearable? I don't know; I seek more light on the subject. What I do know is that if the news bulletin follows a dance band programme, hardly a word is intelligible until someone has moved the TC knob a long way clockwise. This preference for muffled (mellow is, I believe, the accepted term) reproduction is all the more puzzling since the majority of the sets that one comes across in messes and canteens have little enough "top" anyhow. Someone—I think it was "Cathode Ray"—once wrote that the dial of the average cheapish commercial receiver might well have four positions marked "very woomphy," "woomphy," "not quite so woomphy," and "still pretty woomphy."

Senile Decay?

That, I feel, is no very great exaggeration. But sometimes I am assailed by a doubt: do receivers sound woomphy to me because my aged ears have lost some of their high-note response? Do I like the tone-control turned farther clockwise than the young dance-music enthusiasts would have it owing to the sad effects of senile decay? It is, of course, a fact that once you are over thirty or so your ears respond less and less well to high frequencies. Hence grave and (we hope) reverend seniors might need the tone control turned clockwise in order to be able to hear the upper notes that are clearly audible to gilded youth. Is it then really the ears of the older folk that woomph rather than the loudspeakers of our wireless sets? I hardly think this can be so, for I notice that the young, too, are unable to comprehend the news when it is reproduced with the dance-music settings of their choice.

"Photograms of the Year"

THIS popular pictorial annual, now in its 43rd year, has again appeared. It constitutes a record of the year's progress in the photographic art, and includes pictures from many parts of the world. *Photograms* is issued by our Publishers and is obtainable from booksellers and photographic dealers at 7s. 6d. in paper cover or 10s. bound in cloth.

VELOCITY-MODULATION U-H-F GENERATORS

Explaining Their Operation

By
GEOFFREY BOCKING
(Pasta Developments, Ltd.)

DURING the past few years the focus of interest in radio engineering has been rapidly shifted towards the use of higher and higher frequencies. It is well known that a valve having a conventional electrode structure becomes progressively less and less efficient as a generator or amplifier as the frequency is increased; beyond approximately 100 Mc/s it may be considered useless for purpose.

Although generators for the ultra-high frequency have been available for several years it had not in general been found possible to secure operating efficiencies comparable with those easily achieved at lower frequencies, and considerable research was, in consequence, devoted to improving this position. Much interest was aroused, therefore, when in 1936 and 1937 announcements appeared in the American technical Press of ultra-high-frequency generators called "rhumbatrons" and "Klystrons," for which high efficiency was claimed. The outbreak of hostilities in Europe and the attendant increased importance of

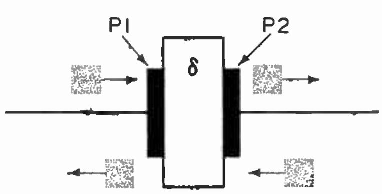


Fig. 1. A simple parallel-plate condenser, showing diagrammatically the relative movement of electron charges.

the ultra-high-frequency field has resulted in little information being published here on recent developments of these generators.

Space-charge Influence Effect.—The first operating principle is that, for an alternating current to flow in a conductor, it is not necessary for the generator to have a conductive connection with the conductor; it may be readily induced by a "space-charge" whose density is made to oscillate. This may be made clear by considering the simple condenser of Fig. 1. P_1 and P_2 are plates of equal area and thickness separated by δ, a dielectric medium. When the condenser is discharged the potential difference between the plates is zero and no lines of electrostatic force pass through the dielectric. If a charge or quantity of electrons is added to P_1 a similar charge or quantity of electrons will depart from the surface of P_2; that is, a current will flow within P_2. Similarly, if the charge applied to P_1 is continually imposed and withdrawn, the current within P_2 will alternate in direction. It is obvious that P_1 here performs the function of a conduction means whereby the proximity to P_2 of a quantity of electrons or charge may be varied. This result may equally well be achieved by using a thermionically emitted electron cloud or space-charge, and varying its density or position with respect to P_2, causing a varying current to flow in it. This is the *modus operandi* of the troublesome effect met with in certain frequency-changer valves where the oscillations generated in the oscillator section causes an oscillating space-charge to appear before the signal grid; thus undesirable coupling occurs between the two. Consideration of the foregoing will show that for adequate power to be induced in a load connected between the two real or effective plates, this load must possess adequate impedance. In practice, as the frequency of alternation becomes progressively higher, a high impedance becomes more difficult to develop; high resistances become short-circuits and above 100 Mc/s conventional resonant circuits become impracticable. This leads to the second operating principle :—

Cavity Resonators.—In 1894 Sir Oliver Lodge demonstrated to the Royal Institution that if an electromagnetic generator be placed within a suitably constructed hollow pipe, the electromagnetic energy could be confined within the pipe during its travel along it and projected as a beam from the open end. The mathematical theory of these "wave-guides," as they have later been called, was developed by Lord Rayleigh in 1897, and from then until 1936 their possibilities seem to have been overlooked. In that year, however, W. L. Barrow and G. C. Southworth published results of their independent experiments on guided waves in hollow pipes, and these papers have been followed by many others. It has been found that by so arranging the physical dimensions it is readily possible to develop standing waves in a hollow pipe system, the resulting configurations, called "cavity resonators," having high impedance and convenient practical construction. Various types of wave are possible in cavity resonators and are differentiated solely by the relative disposition of the lines of magnetic and electric force. They may be excited by placing a loop at right angles to the magnetic lines of force (magnetic excitation)

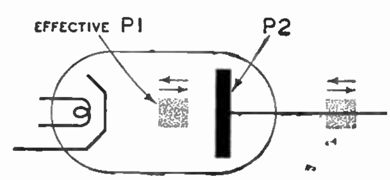


Fig. 2. A condenser in which one effective plate is formed by an electron cloud or "space-charge."

or by a conductor or electron stream parallel to the lines of electric force (electrostatic excitation). This last method of excitation, by an electron stream, is of interest here. Its practical realisation raises difficulties, however, and their solution is dependent upon the third operating principle :—

Velocity-modulation and Phase-focusing.—At low frequencies and in a vacuum electron velocity is so great and consequently the "transit-time" or time taken by an electron to move from point A to point B in a circuit is so short, that no error arises in considering the velocity to be infinite. At ultra-high frequencies, however, the transit-time may become comparable to the period of one cycle, and the induction by oscillating space-charge as given above is complicated thereby. A considera-

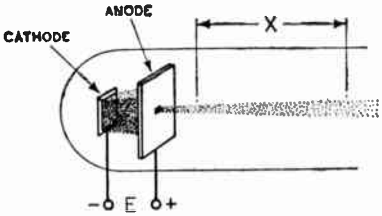


Fig. 3. Simple generation of an electron stream.

tion of this problem is therefore desirable.

The velocity of an electron in a vacuum is dependent upon the square root of the fall of potential through which it passes. Electrons issuing from the hole in the anode shown in Fig. 3 will continue with a velocity given by the formula:

$v = 6 \times 10^7\sqrt{E}$, where v is the electron velocity in cm/sec. E is the anode voltage in volts.

At this velocity the electron stream will traverse a distance of x cms in t seconds, where $t = x/v$.

It should be emphasised that this time may be varied at will by changing the anode voltage E, practical considerations imposing upper and lower limits to this variation.

As shown in the description of the first operating principle of inducing an oscillatory current in a conductor by means of an electron cloud or space-charge, the density or proximity to the conductor of the charge must be varied at the frequency of the desired oscillation. An electron stream generated as shown in Fig. 3 may be arranged to do this at moderately high frequencies by interrupting the flow of electrons at such a rate that a cloud of electrons arrives opposite the conductor, and in consequence the conductor receives a pulse of energy in phase with the resonant frequency of the load connected to it. This is shown diagrammatically in Fig. 4.

This method is impracticable at ultra-high frequencies, however, for two reasons:—(1) The difficulty of securing a resonant load having a sufficiently high impedance at these frequencies. In consequence a resonant cavity must be used. (2) The physical dimensions of a suitable cavity necessitate considerable length along the axis of the electron stream. The transit-time of this stream will therefore normally be equal to the period of several cycles of the resonant frequency of the cavity.

The significance of this latter disadvantage may be appreciated by reference to Fig. 5. During the whole of the time that the electron cloud is within the cavity, it has the same influence upon it irrespective of its position (as shown in the upper diagram); whereas for resonance to be excited, the influence should vary as shown in the lower diagram. This might be overcome by making the velocity high and the transit-time short, but this would necessitate increasing the voltage E. Since the power supplied to the generator increases as the square of E ($P = E^2/R$) and the velocity only increases as the square root of E ($v = 6 \times 10^7\sqrt{E}$), the efficiency falls more rapidly, due to the increase of energy supplied, than it rises due to reduced transit-time effect.

The solution to the above dilemma may be appreciated by considering a well-known schoolboy problem in mathematics: "If a train A starts with a velocity v_1,

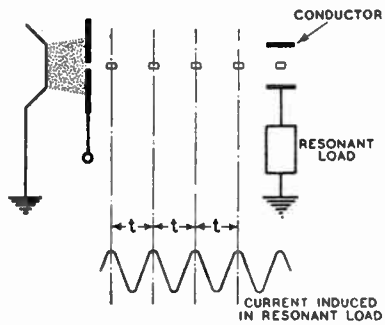


Fig. 4. Excitation of resonance by pulses of current induced by an interrupted electron stream.

and T hours after a second train B starts with greater velocity v_2, how far must they travel before B overtakes A?" Assuming this to be solved, suppose that at the point at which B overtakes A there is a level crossing, the gates of which have been negligently left closed; it will be obvious that the energy available for the *immediate* destruction of the gates will be greater at this point where the trains run side by side than at any other point on the line where one runs in front of the other.

If this principle is applied to an electron stream, the velocity of successive electrons of which is made successively greater, it will be apparent that at one point all electrons will overtake one another to form a "bunch" and that the

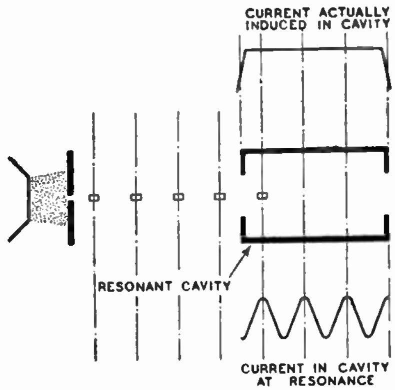


Fig. 5. Showing failure of an interrupted electron stream to induce resonance in a conductor having considerable length along the axis.

influence effect of this bunch at the point of its formation will be greater than that of its component electrons at any other point. In the case of the cavity resonator and electron stream given above, it is possible by suitable design to arrange the bunch to occur once per cycle at, for instance, the point where the stream leaves the cavity. Then, spread out along the stream behind the bunch will be electrons travelling with varying velocities, the net effect of which (some aiding and some impeding the resonant flux) will be very small compared with the large effect of the bunch.

The elements of an efficient ultra-high-frequency generator operating on the velocity-modulation principle are, therefore:

1. Source of electrons and suitable accelerating and focusing means.

2. A device to impress a variation of velocity on the electron stream (buncher).

3. A resonant cavity to receive the energy from the buncher in suitable form (catcher).

4. Coupling means to ensure correct inter-operation of buncher and catcher.

5. DC return path for the electron stream after passing through the system.

Practical Embodiments. — The development of the first generator to operate on the velocity-modulation principle is commonly credited to R. H. Varian and S. F. Varian, who in 1936 published details of their Klystron generator. In 1933, however, Arsenjewa-Heil and Heil gave details of a device rather similar to the Monotron, to be described later. The method of function was only generally indicated, but there seems little doubt that it was, in fact, the first of the velocity - modulation generators.

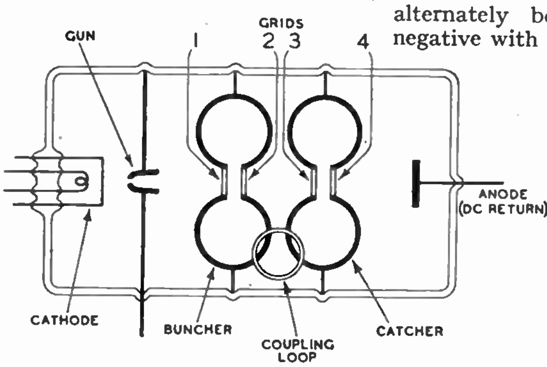


Fig. 6. Essential elements of a Klystron generator. Electrons generated at the cathode are formed into a beam by the gun, whence they pass to the buncher. The buncher varies the velocity of successive electrons and they form bunches just inside the catcher

The Klystron.—Fig. 6 shows the Klystron as it was originally described. The buncher and catcher resonators of identical shape and having, in consequence, identical resonant frequencies, are in the form of toroids in which the re-entrant portions, instead of meeting at the centre, are closed in each case by two grids: 1 and 2, 3 and 4. It was shown in Fig. 3 that a variable velocity could be imparted to an electron beam by passing it through an electrode to which a varying potential was applied. To attempt to secure this velocity modulation with a single electrode would be to encounter the same difficulties as in a conventional valve, and a cavity resonator must be used. The operation is then as follows: assuming oscillations to have been started, oscillatory energy would be fed back from the catcher *via* the coupling loop to the buncher. As a result of this grids 1 and 2 will alternately become positive and negative with respect to each other at the oscillation frequency; this means that the electric field between them will alternately oppose and assist the acceleration field due to the gun, and a variation of velocity will be impressed on the beam.

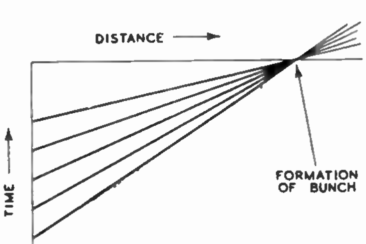


Fig. 7. Showing the velocity imparted to successive electrons arriving after equal time intervals at the buncher.

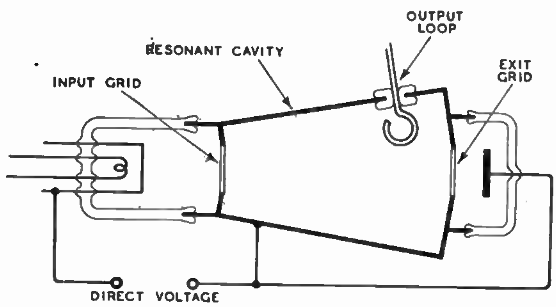


Fig. 8. The Monotron, a simplified version of the Klystron.

The catcher is so disposed to the buncher that the electron stream forms a bunch just within it, the incidence of successive bunches exciting it to resonance.

This explanation is considerably simplified in some respects, but a full understanding can only be achieved in mathematical terms and, in fact, the Klystron has so far defied a complete explanation in such terms. One simplification however, should be immediately apparent from what has already been described: namely, that in a practical Klystron the transit-time within the resonators will be at least an appreciable part of one cycle of oscillation. The electric field will not, in consequence, have a uniform direction during the whole of the transit of the buncher, and velocity modulation must be considered a sum effect of the various accelerations impressed during transit. A simple exercise in integration will show that the effect may be neglected and, when all factors are taken into account, the efficiency is only reduced from a theoretical maximum of 58 per cent. to 40 per cent. in practice.

The Monotron.—Consideration of the voltage relationships within cavity resonators has shown that the function of buncher and catcher may be combined in one resonator. This device has been called the Monotron and one version is shown in Fig. 8. It will be seen that in this case the resonator has considerable length along the axis of the electron stream, so that during the time of transit several cycles of oscillation can occur. During transit, therefore, the electrons are continually being accelerated and retarded, but since this applies equally to all, the bunching effect is governed only by the variations of potential at the input grid. By suitable physical design and applied voltages the bunching may be made to occur in the right phase just at the exit grid. Another valuable feature arising out of this is that the oscillation may equally readily be quenched by application of an incorrect voltage to the resonator, which fact offers a solution to the hitherto difficult problem of modulation. The simplicity of the Monotron and the fact that, unlike the Klystron, velocity modulation and energy transfer occur at single grids, has led to a concentration of development on this type. The results of these labours must for the present, however, remain a matter for speculation.

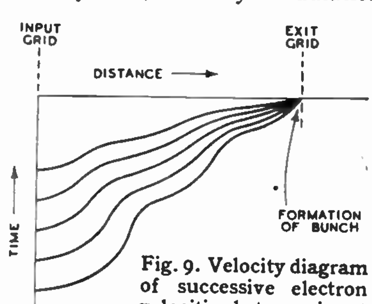
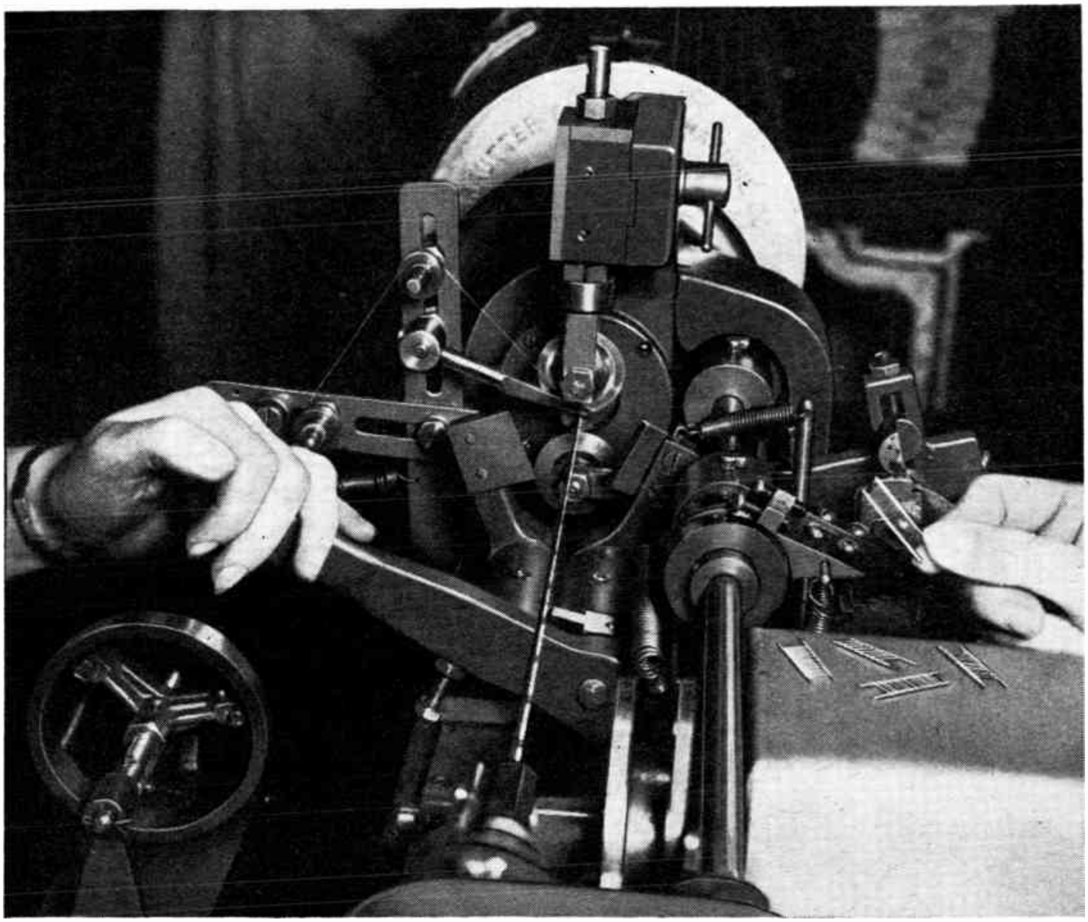


Fig. 9. Velocity diagram of successive electron velocities between input grid and exit grid.

Grid Winding



MODERN technique demands the accurate winding of wire down to a diameter of one-thousandth of an inch—less than half the thickness of the average human hair.

It is also necessary to manufacture specially designed exponentially wound grids, and the machine shown in our illustration takes care of this operation.

BRIMAR

BVA

VALVES

STANDARD TELEPHONES AND CABLES LIMITED, FOOTSCRAY, SIDCUP, KENT.

World Radio History

TOLERANCES

Considerations Governing the Fixing of Limits for Radio Components

By

J. T. TERRY

IT is generally realised that some unavoidable errors must arise in the manufacture of any article. Consequently, it is usual to specify tolerances for the more important physical properties, or parameters, to use a mathematical term meaning the same thing.

Now the customer or consumer tends to request fine tolerances on principle, as it were. This tendency is often one of false caution, particularly in radio, for while in civil and mechanical engineering good workmanship and close dimensions are essential for the first-class performance of parts in continuous mechanical motion, in radio parts are fixed in position relative to each other, so that the experience of other industries cannot be translated directly in this respect. In fact, to demand too close a tolerance may actually be inimical to the interests of all concerned, as will be shown later.

All this is more or less realised by manufacturers of components and has received detailed examination in the more specialised communications journals. Also it has led to standard specifications of various components under the auspices of the British Standards Institution and the R.M.A. The reader may nevertheless find interest in a less rigid review of some aspects of the topic.

It is plain that tolerances which are required in practice cannot possibly exceed the accuracy of measurements. A short examination of what accuracies are possible in laboratory measurement is therefore called for.

Leaving aside the academic question of the fundamental systems of units (e.m.u. and e.s.u.), practical units are derived and commercial laboratory instruments calibrated from the primary standards kept at the National Physical Laboratory and similar institutions in other countries. As explained by Dr. Hartshorn of the N.P.L. in the "Reports on Progress of Physics" for 1939, the units of mass and length may be determined with a maximum accuracy of 1 part in 10^9. Time intervals, and hence frequency, are common to all systems of units and can be readily checked to within 0·5 parts in 10^8. A considerable drop in accuracy obtains, however, when electrical quantities are considered. Table I indicates the best which the Electricity Department of the N.P.L. guaranteed in 1936.

TABLE I.

Precision of some electrical measurements. (NPL, 1st grade).

Quantity.	Accuracy.
Resistance	10 parts in 10^6
Volt- and Ammeters	1,000 „ „
Capacity of screened condenser	100 „ „ or $0.01\mu\mu F$ for fixed condenser
Capacity of unscreened condenser	$0.1\mu\mu F$ for fixed condenser

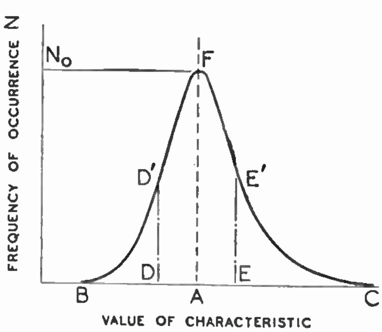


Fig. 1. Frequency distribution curve showing the relationship between the value of a given characteristic and the number of articles having that value.

In addition to this inherent limitation of accuracy it must be remembered that even laboratory standards are subject to drift. Moreover, unknown objects may be measured only by means of multiplying or dividing networks, or variable sub-standards or both; hence, the accuracy of works laboratory measurements is generally one or two orders of magnitudes below that of N.P.L. standards, although in some cases incremental readings of the variable standards may be used, e.g., in parallel substitution measurements, yielding results of precision similar to that with which the sub-standard is known. This will be realised on examining Table II.

TABLE II.

Precision of some comparative measurements.

Parameter	Accuracy of Comparison.
Resistance	<0.1 in 10^6
EMF	1 in 10^6
Capacity	$0.001\mu\mu F$ (calibration of good micrometer condenser)

Table II does not necessarily improve matters unless the customer supplies a sample to the manufacturer for comparison. Rather, Table II indicates that such sources of error as setting accuracy, scale resolving power and backlash may be overcome in good laboratory equipment so as not to impose further limitations on Table I.

Production Aspect

The characteristics of mass produced articles follow the "Normal Distribution Law." This means that when a large number of articles are made and the same parameter is measured for each one of them a graph connecting these values with "frequency" will be of the nature of Fig. 1.* "Frequency" in its present sense has no connection with $\omega/2\pi$, but denotes the number of specimens having the parameter value indicated by the abscissæ. Fig. 1 shows that while the value A is particular among all the other possible values inasmuch as A occurs most frequently (N times) the total number of com-

* See "Statistics and Engineering Practice" by B. P. Dudding and W. J. Jennett, *J.I.E.E.*, July, 1940.

Tolerances—

ponents having other values (i.e. from B to C, excluding A) is much larger. It is consequently not possible to admit of the value A only, in practice. The points E and D illustrate the significance of tolerance limits: the number of acceptable components is represented by the area DD'FE'E, and would have a definite value under given conditions of production. Hence, constant observation of this area is regarded as an essential feature of the modern production process, for any serious defect in the manufacture is likely to show up at once as a reduction. This watch is kept by means of laboratory checks, carried out for the sake of economy and expediency on numerically small samples chosen at random from a large group—the day's output of the component say.

An example may help to elucidate this. Consider Fig. 2 which was obtained from measurements

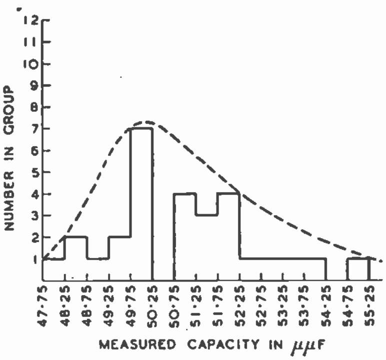


Fig. 2. Distribution curve for 29 condensers with a nominal capacity of 50μμF ± 10 per cent.

on a sample of 29 condensers with a nominal capacity of 50μμF. Owing to the limited number, the diagram shows discontinuities, but these would gradually disappear if more samples were examined, and the shape of the dotted envelope curve of Fig. 2 would approximate to that of Fig. 1. Fig. 2 shows that some 25 per cent. of the samples are within ±½ per cent. of their nominal value. Clearly, it would be uneconomical to specify this tolerance, as 75 per cent. of the production would have to be rejected. Actually, the particular condensers were made to a specified tolerance of ±10 per cent., and are thus all within the limits.

The example does demonstrate however, the trend towards a higher percentage of rejection if closer tolerances are specified. Also, allowance should be made for drift in shop sub-standards, as distinct

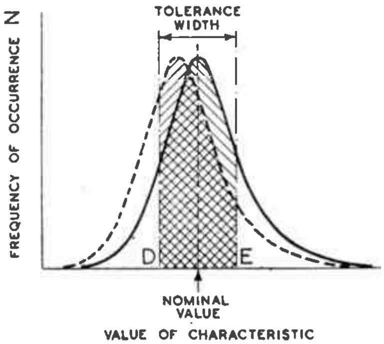


Fig. 3. Showing reduction in number of acceptances resulting from drift in the shop sub-standard.

from laboratory standards. This is illustrated in Fig. 3, showing the effect of a small drift in the value of the shop standard: the distribution curve has been displaced and instead of the number of acceptable articles represented by the shaded area under the full line curve, only the much smaller number (shaded area under the dotted curve) may now be passed.

As many factors contribute to make such displacements unavoidable in practice, expediency demands that the closest tolerance specified should be well in excess of the uncertainty inherent in shop standards. The above also applies although to a lesser extent, where the customer submits his own standards to the manufacturer, as this valuable procedure eliminates uncertainties regarding standards in the laboratory, but not in the shop.

Consumer's Aspect

While cost and delivery time are the only factors to deter the consumer from postulating the closest tolerance possible, he would be served equally well by what might be termed a "functional" tolerance, i.e. a tolerance which is adequate for the function which the component is to perform. For in any wireless instrument, there are some components whose values are not at all critical, and, conversely, others which are very critical; indeed, some in the second group are so critical that even the closest possible tolerance is inadequate; the precise values of such components are adjusted *in situ*, after assembly of the instrument. Most radio engineers agree that of two contemporary radio sets of similar specification but different manufacture, perfection and permanence of the final adjustments may contribute almost as much as design in making one set superior to the other.

As an example, consider the sensitivity of a receiver. Here, it would be futile to pay much attention as to whether the "Q" of the aerial coil is 100 instead of 105 say, while the mutual conductance of valves varies normally between ±20 per cent. What counts is the tracking of the aerial and oscillator circuits, and their alignment with the IF stages. Trimming condensers and/or permeability tuned coils are essential for this purpose. The variations possible with the former may be anything between 5 and 100μμF, while the figure is 5 to 100 per cent. of total inductance for coils. In these circumstances, it is irrational but usual for the customer to order quantity produced fixed condensers with a nominal capacity of 100μμF, say, and a tolerance of ± ½ per cent. This leaves a margin of just five times over guaranteed N.P.L. measurements. Such a procedure will lead to disappointment. A tolerance of ±2 per cent., say, would have been quite adequate, and a simpler proposition for the makers.

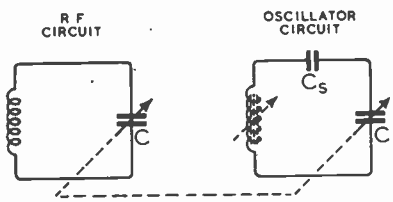


Fig. 4. Basic superhet circuit for the estimation of tolerances.

Next, consider as another example, the series padding condenser C_s in the oscillator circuit of a superhet receiver (Fig. 4): The two nominally identical sections of a variable condenser tune the RF and the oscillator circuits, alignment being provided for in the values of the inductance and the series padder C_s. The effective or total capacity of C_s and C in series is $C_T = \frac{CC_s}{C + C_s}$.

The effect of a change δC_s in C_s on the value of C_T may be calculated by simple differentiation; this shows that the fractional change in C_T will be

$$\frac{\delta C_T}{C_T} = \frac{C}{C_s + C} \cdot \frac{\delta C_s}{C_s}$$

With a typical variable condenser (50 to 550$\mu\mu$F) for C, and a nominal value of 5,000$\mu\mu$F for C_s, the medium wave band extends from 200 to 650 metres say. Then, at 200 m.

$$\frac{C}{C_s + C} = \frac{50}{5050} \doteqdot \frac{1}{100},$$

and $\frac{\delta C_T}{C_T} = \frac{1}{100} \cdot \frac{\delta C_s}{\delta C_s}$;

and at 650 m.

$$\frac{C}{C_s + C} = \frac{500}{5550} \doteqdot \frac{1}{11},$$

and $\frac{\delta C_T}{C_T} = \frac{1}{11} \cdot \frac{\delta C_s}{C_s}$

The effect of a small departure of C_s from its nominal value will obviously be negligible at 200 m; while at 650 m, it may cause some error in the calibration of the wavelength scale. Loss in sensitivity will hardly be experienced, owing to the flat top of the aerial circuit response curve. Allowing a maximum error of 3 m. this corresponds to a percentage error of

$$\frac{3}{650} \times 100 \doteqdot 0{\cdot}5 \text{ per cent. in}$$

wavelength, and twice this amount, i.e. 1 per cent. in effective capacity.

Hence, $\frac{\delta C_s}{C_s} = \frac{11 \times \delta C_T}{C_T} = \pm 11$ per cent. would be the permissible tolerance of the series padding condenser. A closer tolerance of ± 5 per cent. could be easily guaranteed, yet customers frequently specify ± 1 per cent. for this type of condenser. In a particular case, which probably applies to all manufacturers, a $\pm$ 1 per cent. tolerance would have been a simple matter for capacities of the order of 100$\mu\mu$F, but very difficult for condensers of the order of 5,000$\mu\mu$F: evidently, a little co-operation between customer and manufacturer would have arrived at a wider tolerance, speeded up delivery and, incidentally, reduced costs.

Next to the sensitivity of a set, its selectivity and fidelity may be considered the most important measures of performance. Here again, it may be shown that wide limits for the values of components are permissible. For instance, cathode bias resistors produce a self-regulating effect and thus allow of quite large tolerances. This is actually well realised, as a consequence, the preferred range of values and tolerances of the larger resistor manufacturers ensures that no item of their maufacture can be rejected because of incorrect values!

Earlier in the war, an advertisement by a well-known firm of set manufacturers revealed that the substitution of 10 per cent. tolerance resistors for 2 per cent. resistors could at the worst lead to a 6 per cent. change in sensitivity; they claimed that this could hardly be noticed. In view of the much wider tolerances usual in valves, not to mention output transformers and loudspeakers, their claim may be viewed as a model of understatement.

Similar considerations apply to measuring apparatus. Since the advent of negative feedback, suitable design renders their precision largely a function of the perfection and permanence of tuned circuits and resistor adjustment, and the conforming of a meter to a specified law—usually of the straight line type. There is some danger in pushing too far the plea for more liberal tolerances, as one might find oneself arguing that the performance of a given circuit is independent of all its component values. This is avoided by careful study of the given problem. As an example, the gain of a Class A voltage amplifier (without feedback) using a pentode with self-bias and screen voltage dropping resistors is essentially determined by the geometry of the valve and the value of the load impedance; while if a large amount of negative feedback is used, the gain is essentially determined by the feedback ratio and rather independent of valve slope and load impedance.

Again, there is the danger of cumulative tolerances. Thus, in the last example but one, tolerances would be cumulative if slope and load impedance were both low, or both high. If the tolerances were ± 20 per cent. and ± 10 per cent. say, the gain of the stage would vary by ± 30 per cent. very nearly; in other words, the difference in the gain of two similar stages, one of low and the other of high value components, would be 60 per cent. Reverting to the case of the simple tuned circuit, it can be shown by simple differentiation that a small change in its inductance or capacitance will change its resonant frequency by half that amount, and in the opposite direction. For large changes, however, use must be made of the complete formula:

Percentage change in resonant frequency $= 100 \left[\sqrt{\frac{1}{1+p}} - 1. \right]$

where p is the fractional amount by which the actual capacity or inductance differs from the nominal. This equation is plotted in Fig. 5 showing that for fairly high positive changes of inductance or capacity changes in frequency are more pronounced than for small or negative component errors.

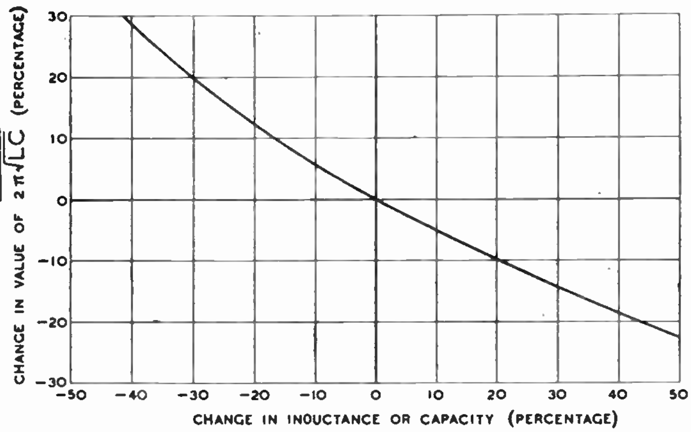


Fig. 5. Relationship between change of inductance or capacity in a tuned circuit and change of resonant frequency.

Tolerances—

Hence, in specifying the widest possible tolerance for a given component, the tolerances of other components in the circuit must be considered at the same time.

Some readers may by now have concluded that sacrifice of quality for the sake of quantity and cheapness is advocated. Quite the contrary; as a matter of fact resources are frequently wasted on ensuring a needlessly close tolerance, and consequently, far more important properties of the component are neglected. To revert to an earlier example, tuned circuits can usually be adjusted as closely as desired to the wanted frequency or frequency law. It is then most desirable that the circuit adjustment should not alter appreciably with time, temperature, humidity and pressure. In other words, what matters is not so much the precise value of the component parameter, but the permanency of this value when adjusted. Yet this is generally ignored by purchasing departments which may specify a very close tolerance for the initial value of a component, but none at all for, say, its temperature coefficient!

Fitness for Purpose

In this connection it is an encouraging sign that one of the most reputable firms of English instrument makers has adopted the slogan "Good enough for the job" in advertising a new product which by its robustness and availability is an improvement over earlier types, while its low tolerances are still adequate in most applications. Since production went up one may take it that slow if beautiful craftsman's methods had to be put aside. But such a step is basically due to the requirements of mass production technique and merely brought home more rapidly by the war. As mentioned before, it need not lead to a sacrifice of quality. Actually, mass production methods can be combined with a high degree of accuracy and workmanship.

Summary

Present day mass production methods require generous tolerances for component parameters. It is almost always wrong to insist on very close tolerances as this may slow down delivery and lead to more important properties being overlooked. Quality need not suffer if semi-adjustable components are used—possibly as additions to a fixed component—in those sections of the circuit which determine its performance, for such adjustments are necessary at any rate during final test.

Closer co-operation between customer and manufacturer and greater technical awareness of sales and purchasing staffs are essential for the realisation of optimum specifications. The difficulties and requirements of both sides can usually be met if there is sufficient interest to try and understand them. This would increase not only the volume but also the quality of production, and perhaps bring nearer the time when components such as valves, transformers, coils and condensers will be standardised as rationally as resistors are to-day.

BOOKS RECEIVED

The Amplification and Distribution of Sound, by A. E. Greenlees.—This is a revised second impression of a standard work for PA engineers, reviewed originally in the issue of this journal dated March 16th, 1939. The revisions are of a minor character and do not affect the main body of the next. Pp. 255 with 82 diagrams. Published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C.2. Price 12s.

Instruction Manual for Cossor Ganging Oscillator.—Although intended primarily as a manual for the Cossor Model 343 Oscillator, this booklet stands by itself as a comprehensive treatise on coupled RF circuits and their response curves, and as such is sold separately from the instrument. It is liberally illustrated with circuits and CR oscillograms and contains a useful bibliography. Pp. 44 with 36 diagrams. Published by A. C. Cossor, Ltd., Highbury Grove, London, N.5. Price 3s. 6d.

Frequency Modulation. By K. R. Sturley. This is the first of a series of monographs containing information on specialised subjects to be issued by *Electronic Engineering*. The subject-matter of the present publication is based on a series of articles by Dr. Sturley that have recently appeared in that journal. The advantages and disadvantages of frequency and phase modulation are considered in detail, and there is a very full discussion of the FM receiver. Pp. 58; 30 figures. Published by *Electronic Engineering*, 43, Shoe Lane, London, E.C.4. Price 2s. 6d. (by post 2s. 8d.).

Six-figure Trigonometrical Tables. Giving the six trigonometrical ratios for every minute of arc. Definitions and formulæ that are likely to be required in using the tables are included. In pocket size; pp. 54. Published by the Ford Motor Company, Ltd., Dagenham, Essex. Price 1s. 6d. by post.

Experimental Radio Engineering. Second Edition. By E. T. A. Rapson. Describing a number of experiments and methods of measurement devised for use in a three- or four-year course in radio engineering at a technical college. The experiments range from the illustration of simple resonance and the determination of valve characteristics to overall receiver tests and electro-acoustic measurements. Pp. 159; 170 figures. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 8s. 6d.

Foyle's Technical Books Catalogue.—More than 450 subjects, including radio and electrical engineering, acoustics and mathematics for engineers, are dealt with in the November, 1942, edition of this catalogue issued by W. and G. Foyle, Ltd., 119-125, Charing Cross Road, London, W.C.1.

Conserving Paper

The Waste Paper Recovery Association points out that, as less paper is now going into the home, it is becoming increasingly difficult to meet our war needs by merely salvaging all paper in current use. It is therefore essential that the consumption of paper must be drastically reduced.

THE WORLD OF WIRELESS

SOUND REPRODUCTION

THE technical basis of sound reproduction was the subject of a paper read by Dr. L. E. C. Hughes at the meeting of the British Institution of Radio Engineers held in the Lecture Hall of the Institution of Structural Engineers on November 21st.

In outlining the scope of his discourse, Dr. Hughes pointed out that a high degree of perfection had been attained in the individual components of the sound-reproducing chain—microphones, amplifiers, etc. —but that there were still many factors which could introduce distortion and unwanted components in the sound reaching the ear. Among these he gave as instances the blurring effect of reverberation, the properties of the ear in relation to loudness and the limitations of single-channel systems of sound transmission.

Listening tests were still the only reliable means of arriving at a final estimate of quality, and he gave details of the methods used to compare the original with the reproduced sound in selecting receivers for approval by the Central Council for School Broadcasting.

A lively discussion of these methods occupied the question time, which gave Dr. Hughes the opportunity of adding statistical evidence of the consistency of the results obtained.

AMERICAN AMATEURS

WHILST the recently formed American War Emergency Radio Service for the maintenance of civil defence communications systems is not exclusively a service for amateurs, it has certainly been a clarion call to them to make use of their vast experience in communication networks.

It had been suggested that the amateur stations should be linked to form a nation-wide communication system, but this has given place to the present scheme, which does not involve the use of amateur stations as such. It is pointed out by *QST* that the W.E.R.S. is making temporary use of amateur frequencies and necessarily counting largely on the support of amateurs and the loan of their gear for the establishment of "Civil Defence Stations" by local governments.

The stations will operate in the 112-116, 224-230 and 400-401 Mc/s amateur bands.

BRITISH LISTENERS

IN reply to a recent question in the House of Commons the Assistant Postmaster-General stated that on August 31st, the latest date for which accurate figures were available, there were 8,836,724 wireless receiving licences in force in this country. He also intimated that since that date the number has increased to over 9,000,000.

The figure for August 31st shows an increase of 211,145 over that for December 31st, 1941. This is, however, about 300,000 fewer than the number of licensed listeners on July 31st, 1940.

IMPORTANCE OF RADIO

THE great increase in the importance of wireless communication, radiolocation and other applications of wireless technique in modern warfare were exemplified by two events occurring during December.

Mr. Lyttleton, Minister of Production, announced on December 9th that it having been considered necessary to strengthen the existing organisation for controlling research, development and production in this field, a Radio Board had been set up "as the co-ordinating body in regard to inter-service policy, research, development and production."

Sir Stafford Cripps, the recently appointed Minister of Aircraft Production, who, in addition to his ability as a lawyer, has a scientific bent, will act as chairman in his personal capacity. Much of the work of the Board is carried out through two main working committees, the Production Planning and Personnel Radio Committee, and the Operations and Technical Radio Committee, of which Mr. Garro-Jones, Parliamentary Secretary to the Ministry of Production, and Prof. G. P. Thomson, F.R.S., are respectively chairmen.

The membership of the Board includes representatives of the Admiralty, War Office, Air Ministry, Ministry of Supply, Ministry of Aircraft Production, and General Post Office, as well as several special non-departmental members.

It will be remembered that when the Prime Minister asked Sir Stafford to accept the post of Minister of Aircraft Production he said "the production of aircraft and the development of radio technique lie at the very heart of our affairs."

Another important event concerning radio was that the German-controlled Philips factory at Eindhoven, Holland, had been considered of sufficient importance to send nearly

The World of Wireless—

100 light R.A.F. bombers to deliver a low-level, concentrated attack on the factory in daylight. The works include the largest valve manufacturing plant in occupied Europe, the whole of the production of which goes to the Nazis.

EMPIRE BROADCASTING

TEN years have passed since the opening of the Empire Service by the B.B.C. To record the story of the service and the advance made during this first decade of regular broadcasts from this country for oversea listeners the B.B.C. has issued an illustrated booklet, "Calling All Nations."

Although it was not until December 19th, 1932, that the Empire Service was introduced, it was five years earlier, in November, 1927, that the B.B.C., by arrangement with Marconi's Wireless Telegraph Company, established the 7-kilowatt experimental short-wave transmitter, G5SW, at Chelmsford. It will, however, be remembered that *Wireless World* agitated for the introduction of Empire Broadcasting, a term which we coined, before the opening of the Chelmsford station.

At first the official attitude of the B.B.C. was to throw cold water on the scheme, but we continued to plead that it be given a trial. Our opinions on the practicability of our effective Empire Service were soon confirmed by the successful transmissions to the Netherlands East Indies from the Dutch station, PCJJ, at Eindhoven, in March, 1927.

Great strides have been made in short-wave transmission in the past few years, and with the increased number of transmitters the B.B.C. is literally "calling all nations"—in forty-seven languages. In September, 1939, the B.B.C. was broadcasting in nine languages only.

Whilst for security reasons it is not possible to say how many transmitters are at present in use, it is significant that fourteen short wavelengths can now be employed simultaneously.

Tribute has been paid in the 64-page booklet, which costs 1s., to the considerable help given by listeners oversea in building the service. Without their help it would have been impossible, especially in the early days, to determine how successful were the efforts of the broadcasting engineers.

U.S. SHORT-WAVES

SHORT-WAVE listeners will have noticed the considerable improvement in the quality and power of the transmissions from the Schenectady short-wave transmitter of the General Electric Co. This has been due to the inauguration of the new 100-kW WGEO transmitter. It has been built to replace a similar one transferred to KWID, San Francisco, some months ago to combat Japanese broadcasts in the Pacific.

IN BRIEF

Empire News Bulletins

NEWS in English is daily transmitted by the B.B.C. in its European and World Services at the following times (BST) and in the wavebands listed.

0200	49, 31	1400	25, 19
0345	49	1600	31, 25, 19, 16
0530	49, 41	1700	31, 25, 19, 16
0715	41, 31	1900	25, 19
0900	41, 31, 25	2045	31, 25, 19
1000	49, 41, 31, 16	2245	49, 41, 31, 25*
1200	25, 19	2345	49, 31

* Except Sunday.

Radio Relay Statistics

ACCORDING to statistics just published there were 398,985 subscribers to 278 radio relay exchanges at the end of June, 1942. This was an increase of 11,751 subscribers in three months.

NEWS IN ENGLISH FROM ABROAD

REGULAR SHORT-WAVE TRANSMISSION

Country : Station	Mc/s	Metres	Daily Bulletins (BST)
America			
WNBI (Bound Brook)	17.780	16.87	2.0†, 2.45‡, 4.0§‡, 6.0.
WRCA (Bound Brook)	9.670	31.02	7.0 a.m., 9.45 a.m.
WRCA	15.150	19.80	2.0†, 2.45‡, 4.0§‡, 6.0.
WGEO (Schenectady)	9.530	31.48	9.55 a.m., 9.0†, 10.55§‡.
WGEA (Schenectady)	15.330	19.57	9.0 a.m., 2.0, 3.0, 7.45§‡, 11.0.
WBOS (Hull)	11.870	25.27	12.45 a.m.†, 12.0 mdt.
WBOS	15.210	19.72	9.0 a.m., 2.0†, 2.45‡, 4.0§‡, 6.0.
WCAB (Philadelphia)	6.060	49.50	6.0 a.m.
WCBX (Wayne)	15.270	19.65	11.30 a.m., 3.30, 7.30‡, 9.30.
WCRC (Wayne)	11.860	25.30	11.30 a.m., 3.30, 7.30‡, 9.30.
WCW (New York)	15.870	18.90	3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0.
WCDA (New York)	17.830	16.83	1.0, 2.0.
WRUL (Boston)	11.790	25.45	9.30‡.
WRUL	15.350	19.54	1.0, 9.30‡.
WLWO (Cincinnati)	6.080	49.34	6.0 a.m., 7.0 a.m.
WLWO	11.710	25.62	7.0, 8.0, 9.0, 10.0.
WLWO	15.250	19.67	3.0, 4.0, 5.0.
Australia			
VLQ6 (Sydney)	9.580	31.32	7.0 a.m.
VLQ5 (Sydney)	9.680	30.99	8.0 a.m.
VLG3 (Melbourne)	11.710	25.62	8.0 a.m.
China			
XGOY (Chungking)	11.900	25.21	2.0, 4.0, 5.15, 9.30.
French Equatorial Africa			
FZI (Brazzaville)	11.970	25.06	8.45.
India			
VUD4 (Delhi)	9.590	31.28	8.0 a.m., 1.0, 3.50.
VUD3	11.830	25.36	3.50.
VUD3	15.290	19.62	8.0 a.m., 1.0.

Country : Station	Mc/s	Metres	Daily Bulletins (BST)
Spain			
EAQ (Aranjuez)	9.860	30.43	6.15.
Sweden			
SBU (Motala)	9.535	31.46	10.20.
SBT	15.150	19.80	4.0.
Turkey			
TAP (Ankara)	9.465	31.70	7.15.
U.S.S.R.			
Moscow	5.890	50.93	11.0.
	6.970	43.04	11.45.
	7.300	41.10	8.0, 9.0, 10.0, 11.0.
	7.360	40.76	11.0.
	7.560	39.68	11.0.
	9.390	31.95	4.0.
	11.830	25.36	4.0, 6.0.
	15.110	19.85	2.15 a.m., 12.40, 11.45.
	15.180	19.76	12.40, 11.45.
	15.230	19.70	2.15 a.m., 11.45.
	15.270	19.65	12.40.
	15.750	19.05	1.0 a.m., 2.0 a.m., 11.45.
Kuibyshev	8.050	37.27	8.30.
	13.010	23.06	6.0 a.m., 2.0, 2.45.
	14.410	20.82	2.0, 2.45.
Vatican City			
HVJ	5.970	50.25	7.15.

MEDIUM-WAVE TRANSMISSIONS

Country : Station	kc/s	Metres	Daily Bulletins (BST)
Ireland			
Radio Eireann	565	531	1.40‡, 6.45, 10.0.

It should be noted that the times are BST—**one hour** ahead of GMT—and are p.m. unless otherwise stated. The times of the transmission of news in English in the B.B.C. Short-wave Service are given at the top of this page.

§ Saturdays excepted. † Sundays only. ‡ Sundays excepted.

Radio and Education

The President of the Board of Education recently broadcast a talk on education by wireless. He spoke of the increasing part broadcasting was playing in education in this country and concluded: " Broadcasting is a part of the life of the people to-day, and must be part of their education if education is to be up to date."

The Television Society

A very satisfactory state of affairs was revealed at the Annual General Meeting of the Television Society, held on December 5th. The impression gained was that the Society will be in a strong position to resume more active work after the war.

All the officers were re-elected, and formal business was followed by a lecture on Colour Television by G. Parr, the Lecture Secretary.

Canadian Apparatus

In a summary of the position of the wireless industry in Canada, a correspondent in the Dominion points out that whilst Canadian manufacturers are unable to make permanent-magnet speakers because of the control of essential materials some British manufacturers are still able to export PM speakers to Canada.

It is estimated that the production of radio equipment in Canada will reach approximately $250,000,000 in 1943, as compared with $100,000,000 in 1942.

Brit. I.R.E.

The British Institution of Radio Engineers has moved to new premises at 9, Bedford Square, London, W.C.1. Until such time as the structural alterations necessary to provide a lecture theatre have been undertaken the general meetings will be held at the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1. The next meeting will be held on January 23rd at 6.30, when J. H. Cozens will give a lecture on modern condenser technique, with special reference to electrolytics.

American Pioneer

Roy A. Weagant, Chief Engineer of Marconi's Wireless Telegraph Company of America (later Radio Corp. of America) from 1915 to 1920, died recently in U.S.A. He will be remembered by old-time wireless men as the originator of the "Weagant X-stopper," a device designed to reduce atmospheric interference by a balancing-out process. He was also responsible for important pioneer work in valve reaction circuits and direction-finding technique.

I.E.E. Wireless Section

At the informal meeting of the Wireless Section of the Institution of Electrical Engineers on Tuesday, January 19th, at 5.30, a discussion on "Quartz Crystal Applications" will be opened by Capt. C. F. Booth.

D.C.B. to B.W.C.

A number of American organisations have recently substituted the word "war" for "defence." The Defence Communications Board is now known, therefore, as the Board of War Communications.

"An Essential Institution"

A feature of the American broadcasting system is the preponderance of small-powered local stations. As a result of a recent survey of listeners conducted by the Medhill School of Journalism of Northwestern University it was revealed that some 90 per cent. of Americans listened habitually to the local station. Commenting on this in a recent article in *Broadcasting* the Director of Research writes: "The local radio station has attained an indispensable place in the social structure of the American community. It is regarded as an essential institution, comparable in usefulness and importance with the schools, the churches, and the Press."

Poland's 20,000 Listeners

German statistics reveal that in the region of Poland occupied by Germany (with the exception of provinces incorporated in the Reich) only 20,000 people are authorised to have receiving sets. Nothing could better demonstrate the situation in this country of 95,000 square kilometres with a population of more than ten millions, where before the war there were more than a million listeners.

Transmitting Gear in the U.S.

In an endeavour to ascertain the number of transmitting valves in use in the United States and at the same time to estimate the needs of the broadcasting and telegraph stations for the duration of the war, the U.S. Board of War Communications recently issued a questionnaire to all stations. This is the first move in a scheme to organise a pooling plan for all essential apparatus.

Measuring Cloud Limits

A photo-electric cell is incorporated in the latest type of meteorological balloon designed by a United States Government research worker. It is used to indicate the lower and upper limits of cloud through which the balloon rises. The variations in light intensity as the balloon rises into and emerges from a cloud cause the cell to vary the transmitter frequency, the changes in which are recorded by a ground station.

Obituary

We regret to announce the recent death of Walter L. Fillmore, director of Jackson Brothers, the condenser manufacturers.

St. Dunstan's

The publication of the twenty-seventh annual report of St. Dunstan's calls to mind the great part that wireless plays in the lives of blinded Service men and women. Until they are able to read by touch broadcasting is their main link with the outside world.

"Wireless World" Index

Our Publishers advise us that the index and binding case for Vol. XLVIII of *Wireless World*, January to December, 1942, is expected to be ready by the new year. The index will cost sixpence (postage 1½d.) and the binding case 4s. (postage 7d.). Both will be available from our Publishing Office. Arrangements can be made for binding readers' copies at an inclusive cost of 10s., plus 9d. to cover the postage when returning the bound volume.

UNBIASED

By

FREE GRID

Thank you, "Cathode Ray," but...

I WAS greatly moved to learn from his letter, in the correspondence columns of the November issue, that "Cathode Ray" is still in our midst on this war-torn planet, and very glad to have his assurance that the contributions to the world's literature which appeared over his name in recent issues of this journal really did emanate from his obviously versatile pen and not from that of some base usurper, as my recollections of his pre-war writings had wrongly led me to think. Hitler has much for which to answer.

In order to understand the dialectic methods which "Cathode Ray" employs, in replying to the problem which I publicly propounded to him, it is unfortunately necessary to adopt the methods of the psycho-analyst and probe a little into his past. There is, however, no need to go the whole hog and ask him a lot of indelicate medical questions, as it is only necessary to examine the latter part of his letter to see clearly that in his younger days he served his apprenticeship to the political trade like myself. I well recollect that years ago, when I first put up for Parliament, the local party agent urged upon me that the only hope of saving my deposit was to adopt this very same red-herring dodge of fending-off an awkward question by replying vigorously and emphatically to one which

"Fending-off awkward questions."

nobody had asked. I did as he advised, and always think that I owed my success largely to the fact that I promised to oppose strongly any attempt of the other party to repeal Ohm's Law, which I pointed out would mean that all our houses would be plunged into darkness and our cinemas left silent and deserted.

"Cathode Ray" is obviously as practised a politician as myself, for the question which I asked had nothing to do with that with which he has so vociferously dealt. Briefly, my question was, why is it that a player-piano recording sounds so much more realistic than a gramophone recording of the same pianoforte solo, *ceteris paribus*. I have now been supplied with the correct answer by Mr. A. N. D. Howe, a well-known American savant. The explanation is to be found in our old friend, the "psychic factor" or "mental suggestion." In other words, just because the reproducing instrument is an actual piano, we expect the recording to sound like the original, and so to our befuddled brains it appears to do so.

As for stereophonic reproduction, the player-piano is no more capable of this than a gramophone or radio set, although many of my correspondents seem to think otherwise. I will consider dealing with this question personally in the Brains Trust section, but space and the Editor's temper are both short this month.

Music While You Shirk

AS many of you know the introduction of music-while-you-work programmes into factories is no new thing brought about by the war. It was suggested by myself many years ago that the relaying of wireless programmes to factory operatives might do much to allay the tedium of soul-destroying repetitive work and actually increase production.

I well recollect the first occasion on which my idea was tried out. A large and well-known umbrella factory was equipped with loudspeakers, and all the local dignitaries were invited to take part in the initiation ceremony, the Mayor being delegated to turn on the first programme with a specially made golden switch. Having regard to the nature of the products on which depended the prosperity of everybody connected with the factory from the managing director down to the humblest worker, it was perhaps a little unfortunate that at the moment the Mayor pressed the switch, the B.B.C. orchestra should be churning out, "It ain't a-going to rain no more," a very popular ballad of the period, and it is small wonder that, as the local paper put it, this unfortunate contretemps put a damper on the whole proceedings.

Actually, it was not the B.B.C.'s fault, as it was purely a coincidence that the loudspeakers were switched on at the moment they were, but the broadcasting authorities cannot be absolved from blame in the matter of the present-day music-while-you-work programmes to which several correspondents have drawn my attention. Apparently the B.B.C. department responsible for these particular programmes is so lacking in imagination and so much behind the times in sociological knowledge that it does not realise that the days when the factory worker was considered to be an ignorant creature, with low and vulgar tastes, have long since passed.

No other explanation is compatible with the dreary daily drool of dismal dirges and cacophonous caterwauling churned out in the music-while-you-work feature. At the request of several of my factory readers, I have made a point of listening carefully to these programmes of late, and I find

Music while you *work*.

that they appear to consist of nothing but music (?) of this type. There does not seem to be any attempt to put out music of a rather more elevating character. As one of my factory correspondents puts it, good tuneful music seems to be reserved solely for the shirkers, as these tuneful music-while-you-*shirk* features are not relayed to factories.

I do not ask for super highbrow music which might slow down production rather than speed it up, but is there no *light* classical music available? Even musical comedy stuff would be better than the ultra-lowbrow cacophonous crooning, which at present the B.B.C. music-mangling department evidently thinks is suited to what it imagines to be the intellectual level of the average factory worker. It is small wonder that there are ominous reports of secret sabotaging of the PA gear in certain factories.

Letters to the Editor

Hearing Aid "Dangers" ◇ Meter Repairs ◇ Extending Multivibrator Range

Hearing Aids

THIS letter ought to open with an apology for adding yet another contribution to the many already written on the subject of hearing aids, but as a medical practitioner and a reader of *Wireless World* for the past twenty years I feel I have some justification.

Firstly, I should like to point out that there are many diseases and conditions which are the causative agents in the production of deafness. The treatment required may be medical, surgical, physical, environmental or even psychological, or a combination of these. Therefore, I am of the opinion that in the first place, or as soon as possible, the deaf person should consult an ear specialist. He should decide the treatment, and if this includes the use of an aid, he can prescribe in broad outlines the type required.

As regards types, except in the cases of minor degrees of deafness the valve amplifier is the most useful one, and a good quality, mass-produced instrument at a reasonable price would be a boon. At the same time the questions of size, weight, portability and inconspicuousness should also receive consideration. The deaf do not like to advertise their infirmity.

In nerve or inner ear deafness, perception of the higher frequencies is usually impaired to a greater degree than the middle of the auditory range. Therefore, in these cases, an amplifier with a rising characteristic would be of benefit if not always essential. In deafness due to otoscleroris the patients often hear better in a noisy background, and here the carbon microphone is preferable to the crystal type.

An automatic volume limiter would, no doubt, be a great asset, but generally speaking the patient can look after this feature with a manual control. The final test of the suitability of any instrument, however, will depend upon how much it enables the deaf person to hear, and for this a week's trial in home surroundings is essential.

Lastly, as regards the sale of deaf aids the National Institute for the Deaf has attempted to deal with this situation by keeping a list of approved dealers, but hearing aid clinics probably offer the most satisfactory solutions. Retailers with certificates of competency in the electrical and physiological aspects of the subject provide a suitable alternative.

E. M. JENKINS, M.B., Ch.B.
Gatley, Cheshire.

MR. HAMILTON raises, in your November issue, the most important point since the discussion on "Hearing Aids for the Million" started.

He states: "Those who claim that hearing aids should not be distributed through the wireless dealer have still to show that their views are justified by a material number of deaf people being liable to use dangerously unsuitable aids."

In my experience of nearly 25 years, during which I have come in contact with many thousands of deaf people, I have not met a single person who has complained that any hearing aid has increased his deafness, and deaf people are not reticent with their complaints.

C. B.

Overhauling Moving-coil Meters

"TIFFEY'S" well-written and interesting article gives much valuable information. The following comments may be helpful to the enthusiast who is inspired to try his hand.

"Tiffey's" Fig. 1 is very tempting. But he does not mention that it is about 2½ times the full size of a typical radio meter movement and is, in fact, about the full size of a switchboard meter movement. It is reasonable to assume that the average reader of *Wireless World* is likely to be concerned with the former—an article appropriately referred to by the switchboard-meter-minded as a "miniature." The immediate thought may be, "Yes, but what about the watch-

Letters to the Editor—

maker's eyeglass?" This very useful aid has one drawback. It magnifies all it sees—including the operator's fingers and his tools. Let the beginner therefore set out with no illusions, remembering that the manufacturer employs adolescent female labour for assembling "miniatures," first selecting them for their natural lightness of touch, *and then he trains them*.

Unless he is accustomed to very delicate work the amateur must expect initial disappointments. He may easily ruin at least one instrument before scoring a success. If he can practise on an instrument beyond repair this is the cheapest way of buying his experience. It is not intended to discourage him from trying, but to warn him of the pitfalls. A slightly sticky meter can very easily and rapidly be rendered unusable by the ham-fisted.

"Tiffey" writes: ". . . the meter itself demands only patience, good eyesight and steady fingers for its renovation." Later he writes: ". . . these (the repairs) can be attended to by a patient, unhurried and steady-fingered amateur with a little common sense." From these statements there are some rather dangerous omissions. "Unhurried" should be underlined. Steady fingers are not enough. A very light "touch" is essential. If he lacks this the amateur had best confine his activities to the simpler repairs and refrain from taking the meter to pieces. It should be emphasised that in any case dismantling the movement should only be undertaken as a last resort and then only by one who is capable of tackling the successful dismemberment and reassembly of a wrist watch.

Dirt in the airgap is one of the causes of stickiness. It can be removed with a pipe cleaner, a piece of stiff non-magnetic wire and/or the tweezers, without dismantling the movement. If this is fruitless, check the adjustment of the pivots. This is done by waggling the coil *very gently*, holding it with the tweezers. It should not be dead tight, but lateral play should be at a minimum. If the stickiness remains after adjustment, cleaning the jewels and pivots may work a cure, but this is by no means certain. A cracked jewel or damaged pivots may probably be the cause. A pivot in good condition should score the finger nail. A blunt one will not. Repointing requires skill and experience, a watchmaker's lathe with suitable chuck and a very fine stone. "Tiffey" is probably right in recommending that it shall be left alone. A cracked or scored jewel can be "felt" with the point of a scriber. It is not repairable.

Use only resin as soldering flux. Crack off and remove surplus when cold. It has a habit of coming adrift later and getting in the airgap.

The simplest and most easily handled balance weight is a helix of lead fuse wire wound on a mandrel of copper wire of suitable gauge. It is fixed with a solution of shellac in methylated spirit. This rapidly dries and sets hard. Adjustments are made later with the second-best pair of tweezers warmed in a bunsen flame. This form of weight is far easier and quicker to adjust than any knurled nut, for which the unsentimental may thankfully substitute it.

One final word. If your meter is usable, leave it alone.

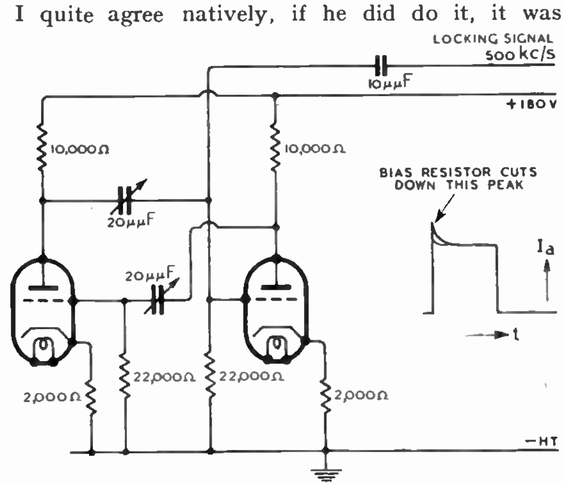
W. R. BISHOP.

London, N.20.

Multivibrators : Extending Frequency Range

IN his article on "Multivibrators" (December, 1942, issue) W. H. Cazaly implies that, in practice, "the upper limit of oscillation frequency is . . . of the order of 200 kc/s or so." I quite agree with this figure for the circuit he shows, but it is by no means a practical frequency limit for a multivibrator.

If a resistance is placed in the cathode circuit of each valve (as in my accompanying diagram), the maximum anode current of the valves is reduced, due to the cathode bias, and the overall change in anode current, and therefore anode voltage, is lowered. This means that the grid condensers are not charged to so great a potential, and consequently discharge quicker, so that the frequency of oscillation is raised.



Multivibrator circuit with cathode resistors.

The apparent increase in frequency is to some extent opposed for:—

(a) The grid-leak resistance is effectively raised.

(b) The anode resistance is effectively raised.

(c) The anode-to-cathode resistance of the valves, which forms part of the discharge path for the grid condensers, is increased.

Even with these opposing effects I have found no difficulty in getting a multivibrator to work at 800 kc/s, using ordinary mains-type triodes.

The cathode resistor also cuts down the initial "kick" in the anode current of the valve, and it is possible to get an almost rectangular anode current wave form (see inset diagram).

I have had a multivibrator with the circuit constants shown on the diagram running absolutely trouble-free for some 15 months at 500 kc/s.

R. COPSEY.

Worcester Park, Surrey.

Player-piano v. Gramophone

ENCOURAGED by the example of resourcefulness displayed by legal luminaries who base their defence on the twofold plea that their client didn't do it, or, alternatively, if he did do it, it was justifiable, I face my critics, Messrs. R. W. Haigh and D'Orsay Bell.

First, adopting a technique employed by St. Paul, I set them to fight it out with one another concerning their diametrically opposite views on the pianist's touch controversy (about which I myself expressed no convictions either way). In the resulting confusion I hope to get by with the argument that my stipulation that the player-piano was properly designed and the record properly made would overcome the technical defect mentioned by Mr. Haigh, and, anyway, it hasn't got much to do with stereophony. Finally, I would remind them that it was "Free Grid" I was answering; again with Pauline technique, by being all things to all men.

"CATHODE RAY."

Transmitter Volume Compression

WHILST fully supporting Mr. King's plea, in your December issue, for the adoption of controlled volume compression in post-war transmitters, I feel that there is a danger that his letter may be misunderstood and gain further currency for the very common misunderstandings already existing on this subject.

Mr. King's first point was that the "range of intensities met with in most musical broadcasts is too wide for the average living room," I was glad to note his subsequent (if somewhat grudging) admission that this was not true in the case of high-fidelity reproduction.

It cannot be too strongly, or too often, emphasised that an ideal receiver must reproduce *at the listener's ear* exactly the same intensities and exactly the same range of intensities as would exist *at the listener's ear* if he were seated in his favourite seat in the concert hall. To this end, a very strong case can be made for the view that a controlled compression at the transmitter should be complemented by a controlled expansion in the receiver—both working to the same law.

To support this case, however, Mr. King pointed out that the present manual control of the intensity range by a monitoring engineer "cannot deal satisfactorily with transients." This is only too true, but the statement contains the clear inference that systems of controlled contrast compression or expansion *can* deal satisfactorily with transients. This is not the case at present.

A contrast compressor or expander is a system designed for the deliberate introduction of "amplitude" distortion—i.e., it is so contrived that the RMS output of the system is not proportional to the RMS input. Further, the essential difference between "amplitude" distortion and "non-linear" (or "harmonic") distortion is the integration time. Thus, if non-linearity of the system is not a function of the RMS value of the input, but is a function of the instantaneous value of the input, then "non-linear" (or "harmonic") distortion is occurring. It seems an inescapable conclusion that, if transients are to be effectively handled, the control of the compressor and the expander must be instantaneous—i.e., the whole system must be based upon the introduction of inverse "non-linear" distortions.

Most critical matching of the law of expansion to that of compression would appear to be necessary if serious residual "non-linear" distortion is to be avoided. In addition, there would be the problem of that interim period during which the system had been brought into operation on the transmitters, but not on all receivers.

These are difficult problems, but they must be faced after the war. Contrast expansion, as it is used at present, is a sheer absurdity, since it is an attempt to correct an arbitrary (and often misguided) manual compression by a wholly unrelated automatic expansion which is inherently incapable of handling transient or very rapid changes in volume.

J. R. HUGHES.

London, N.W.7.

The Editor does not necessarily endorse the opinions of his correspondents

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The Wireless Industry

READERS are reminded that a number of firms have prepared calendars for 1943, but, under existing regulations, copies can only be sent on request, and are subject to a charge. For example, the exceptionally useful calendar issued by British Insulated Cables, Ltd., Prescot, Lancs, is still available at 3d.

Grampian Reproducers, Ltd., have moved to Hampton Road, Hanworth, Middlesex. The new telephone number is Feltham 2657/8.

"DESIGNING A RESISTANCE-CAPACITY OSCILLATOR"

A PARAGRAPH heading was omitted on page 281 of this article in the December, 1942, issue, and the last paragraph on the page should begin: "The separator output amplifier should be designed. . . ."

SHORT-WAVE PHENOMENA

Modified Views on Propagation

TWO abstracts from technical papers of German origin which have recently appeared in *Wireless Engineer* deal with matters of particular interest to those engaged in short-wave work.

The first of these is from a paper[1] by B. Beckmann, W. Menzel and F. Vilbig, and gives details of a particular form of "scattering" in the ionosphere, which results in strong signals being obtained within the skip distance of a transmitter.

As is generally well known, there is, for any particular point on the earth's surface not too far distant from a short-wave transmitter, a certain frequency which, with a given state of ionisation in the ionosphere refracting layer, is the highest that is returned to earth at that point. Waves of higher frequency than this, going up at the same angle, will penetrate the refracting layer, while waves of lower frequency will be receivable at the point in question and also at points nearer the transmitter. Similarly, when the ionisation in the layer is steadily increasing or decreasing, there comes a time for any particular frequency to be the highest which is returned to earth at the given point. At this time all points nearer to the transmitter lie within the "skip distance" *for that frequency*, and refracted waves are not receivable at them.

Weak and Unsteady Signals

Within the skip distance, and beyond the limits of the ground wave, signals of a kind are, however, normally obtainable, but they are of a generally weak and unsteady nature. These are due to the fact that, during the upward passage of the wave towards the F layer, it passes through the E layer, and here a portion of the energy in the wave is "scattered" by ionic clouds which nearly always exist in the lower layer. Some of this "scattered" energy is sent downwards so as to reach the earth within the skip distance for the refracted wave. It must be stressed, however, that this normal type of scattering provides only weak signals, which are not to be compared with those due to a refracted wave.

According to the abstract the German workers carried out their observations at Munich and found that, after that place came within the skip distance for the London 25-m. wave, the London 19-m. wave "could almost always be heard *at great strength*." Of course, Munich would fall within the skip distance for a London 19-m. wave before doing so for a London 25-m. wave. Secondly, the 19-m. transmission of Zeesen, for which Munich was within the skip distance for the whole of the observing period, was frequently audible at *very great strength*, and on these occasions its signals did not, in fact, show any effect of "skipping." These strong signals could not have been due to the normal scattered radiation, and they are explained by the authors as follows: When, after the ionisation in the F layer has fallen below the limit necessary to return the wave to earth at the point in question, the transmission still is not interrupted, because the refracted rays are replaced by other rays which are deflected by the ionic clouds in the E layer on their upward journey, so that they fall more obliquely on the F layer than those going by a direct path. Under these conditions they are refracted by the F layer, and, reaching the E layer, are again deflected, this time downwards to earth.

The E region clouds do not act with the F layer to bring about this result on all occasions, for sometimes there is only the normal weak reception, which is due to the scattering from the E layer clouds acting by themselves. But, the German workers state, the strong reception was obtained during 50 per cent. of the observations, and if this is so it would appear that it should be taken account of in the planning of short-wave communication services to points not greatly distant.

Workers other than the Germans have also observed the fact that, at these distances, strong reception on frequencies which should normally skip is often obtainable, but whether it is due to some other effect in the E layer is not yet definitely known.

The other matter of interest to short-wave workers is from a paper[2] by G. Leithauser, dealing with, among other things, the behaviour of the F2 layer. According to the abstract, the author of the paper is not satisfied with the generally accepted theories seeking to account for the daily and seasonal variations in the F2 layer critical frequency, and on this point he will, no doubt, find many to agree with him. Certainly, when it comes to practice, there do seem to be some points which still require explanation, more particularly in the matter of the low working frequencies which—if the measured critical frequencies are correct—should obtain during the summer day. Practical results show that these can often be considerably exceeded.

The critical frequency of the layer, i.e., the highest frequency return for a wave sent vertically up, is generally assumed to be that for the wave which is returned from the point of maximum electron concentration in the layer. According to this idea, all waves of higher frequency penetrate to a point higher than this, where the electron concentration is falling, and so they are not returned.

Attenuation and Frequency

The German writer bases his ideas on the fact that when a wave penetrates into the layer it becomes subject to a type of attenuation which increases with increasing frequency. Under certain conditions, he states, when the critical frequency measurements are made, what is obtained is *not* the point of maximum electron concentration but a point from where, as the electron concentration increases, the attenuation rises with increasing frequency. This means that the point of maximum electron concentration lies higher than the point to which the wave of critical frequency reaches, and that higher frequencies fail to return, not because they penetrate the layer,

[1] Abstract 1279, *Wireless Engineer*, May, 1942.

[2] Abstract 2275, *Wireless Engineer*, August, 1942

but because they are completely attenuated. Thus the critical frequencies recorded for the summer day are too low, and this fact may give rise to all sorts of errors when the vertical incidence measurements are applied to the oblique case, as they are in the practical forecasting of working frequencies. Furthermore, according to the author, the error in the measured critical frequency is not confined exclusively to the summer day.

One would have thought, however, that it would have been relatively easy to determine whether the measured critical frequency was, in fact, due to the point of maximum electron concentration having been reached, or whether, on the other hand, it was due to attenuation of the wave with rising frequency. For example, does the virtual height increase very rapidly at frequencies near the critical frequency? If it does not, the implication would appear to be that the point of maximum electron concentration does lie higher in the layer, and that waves of frequency greater than the critical would, if they did not fail to return because of being attenuated, show increased virtual heights. If, however, the curve of virtual height against frequency is rising almost vertically near the critical frequency, one would infer that the point of maximum electron concentration is being reached, and that the failure of higher frequencies to return is due to penetration of the layer.

Power Effect?

Again, does the critical frequency vary with the power radiated? If it does it would appear that attenuation *is* the deciding factor, because attenuation can be overcome by an increase in radiated power, whereas electron limitation determines the critical frequency quite independently of the power radiated. It ought, therefore, to be possible to determine whether it is, in fact, the true critical frequency which is being measured or not.

On the whole—so far as the abstract goes—one would conclude that, in that part of the paper which deals with F2 layer behaviour, Leithauser has not quite proved his point, and that, to account for the anomalies previously mentioned, further work is necessary. T. W. B.

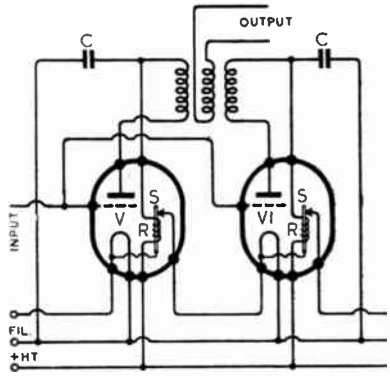
RECENT INVENTIONS

A Selection of the More Interesting Radio Developments

AUTOMATIC VALVE REPLACEMENT

IT is an advantage, particularly in repeater and other "unmanned" stations, to make provision for automatically replacing any valve-unit developing a fault. In the arrangement shown the valve V includes a thermal strip S which closes a contact as soon as the valve goes cold, and so brings a stand-by valve V_1 into operation. The thermal switch is included in the common filament supply so that both valves are initially in circuit, but as soon as the valve V warms up, the valve V_1 is cut out and remains idle until the first valve develops a permanent fault. The closing of the switch may also be arranged to ring an alarm at the nearest terminal or attended station.

In addition to the ordinary dissipation heat, a further temperature control, in the shape of a resistance coil R in shunt



Thermal valve switch

with the anode, may be wound around the thermal strip. As shown, this resistance in combination with a condenser C also serves as a decoupling circuit.

Standard Telephones and Cables, Ltd., and B. B. Jacobsen. Application date October 11th, 1940. *No.* 544447.

UHF TUNING

THE resonant frequency of a pair of coaxial conductors depends upon their distributed inductance and capacity. According to the invention, the tuning of a line circuit of this type is varied by means of a rotatable copper vane which is inserted between the two conductors, preferably at the current loop. In one position of the vane it cuts a maximum number of magnetic lines, and so reduces the overall inductance of the system. When turned through a right-angle it will cut no lines, and there will be no eddy-current effect to reduce the inherent inductance.

A lateral projection at the free end of the vane co-operates with a shaped plate on the inner conductor to vary the capacity between the lines from a maximum to a minimum in step with the inductance.

The arrangement is applied to a receiving system to which the vane is automatically rotated to compensate for frequency drift.

Marconi's Wireless Telegraph Co., Ltd. (Assignees of B. Trevor). Convention date (U.S.A.) June 20th, 1940. *No.* 546069.

SURFACE RESONATORS

A LOW-LOSS tuning device for very high frequencies consists of a hollow ring or toroid of ceramic material with an inside coating of metal, preferably silver. A narrow slit is made around the periphery of the ring to increase the inherent or distributed capacity and to provide an electrode for exciting the element or for coupling it to a load. The internal metal coating screens the ceramic material from the oscillatory field inside the toroid; and so prevents hysteresis losses, as well as frequency drift due to the resultant heating. At the same time the ceramic ring protects the thin silver coating from damage.

Philips Lamps, Ltd. (communicated by N. V. Philips' Gloeilampenfabrieken). Application date July 8th, 1940. *No.* 544475.

RADIO NAVIGATIONAL BEAMS

RELATES to aerial systems for marking out a navigational course or approach path by means of overlapping beams. In some cases the aerials are arranged to radiate beams both to the front and rear. The forward beams are directed across the landing field and form the proper approach path, whilst the others extend backwards and are used either for identification or orientation purposes.

It may happen that objects such as telegraph wires, buildings or trees come within the field of the back beams and reflect part of this radiation field forward, so that it distorts the true path formed over the runway. The invention describes several ways of effectively screening the front beams from the effects of such undesirable reflection from the rear.

Standard Telephones and Cables, Ltd. (Assignees of A. G. Kandoian). Convention date (U.S.A.) January 3rd, 1940. *No.* 545876.

"DUPLEX" TELEVISION

WHEN television broadcasting is resumed there would be no great technical difficulty in providing a better service by increasing the number of scanning lines transmitted per frame. The difficulty is that such an advance would render existing receivers obsolescent.

As a compromise it is proposed to transmit a 600-line scan made up of three interlaced 200-line scans. Existing receivers would then reproduce a 200-line picture, whilst later models, fitted with suitable interlacing means, would benefit to the full extent of the 600-line service. Alternatively, the transmission could be made by scanning a succession of 200-line blue, red, and blue pictures so that the blue lines of the first picture are covered by the red lines of the second picture, and so on. Suitably equipped receivers would then reproduce pictures in colour, whilst older models would still give satisfactory reproduction of a 200-line picture in monochrome.

J. L. Baird. Application date September 7th, 1940. *No.* 545078.

The British abstracts published here are prepared with the permission of the Controller of H.M. Stationery Office, from specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

RECEIVING CENTIMETRE WAVES

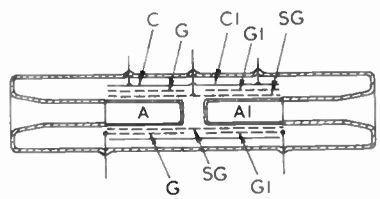
THE filament of a diode, triode or multigrid valve is connected across the centre terminals of a dipole aerial, so that the energy of the received waves varies the electron emission. The filament is preferably pre-heated to a threshold temperature where the effect of the incoming signals is most pronounced.

The terminals of the dipole may be fused into the glass walls of the valve or may even be completely enclosed in it. The filament is connected through chokes to the pre-heating battery, whilst the anode is connected to a high-tension supply through a resistance load across which the rectified signal is developed.

S. R. R. Kharbanda; M. C. Goodall; and Pye, Ltd. Application date, March 21st, 1941. *No.* 540505.

PUSH-PULL VALVE

THE figure shows a high-powered amplifier or oscillator, for push-pull operation, in which both pairs of electrodes are contained in the same evacuated space. The two anodes A, A1 are fitted to a re-entrant part of the glass holder, so that both can be water-cooled. They can also be set close to



Push-pull valves in one envelope.

each other without creating any high-frequency field likely to destroy the welding between glass and metal.

A single screen grid SG, of cylindrical form, surrounds the anodes, and is associated with separate control grids G, G1. The cylindrical cathodes C, C1 are outermost, giving an assembly which is the "inverse" of that normally used. The arrangement permits the use of short grid leads and short cathode supply conductors. Also, since the cathode is of large diameter, it can be made of a number of thin wires, thus giving a high mutual conductance.

Philips Lamps, Ltd. (Communicated by N. V. Philips' Gloeilampenfabrieken.) Application date, August 23rd, 1941. *No.* 546376.

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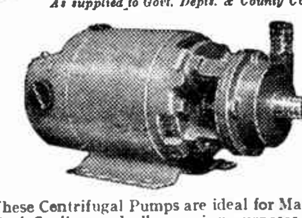

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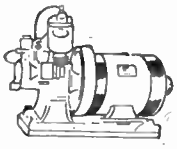

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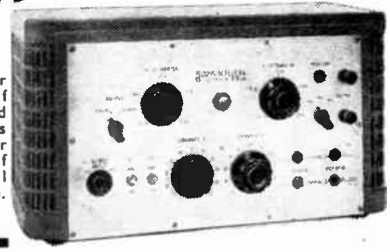

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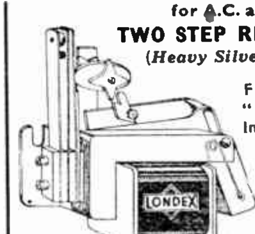

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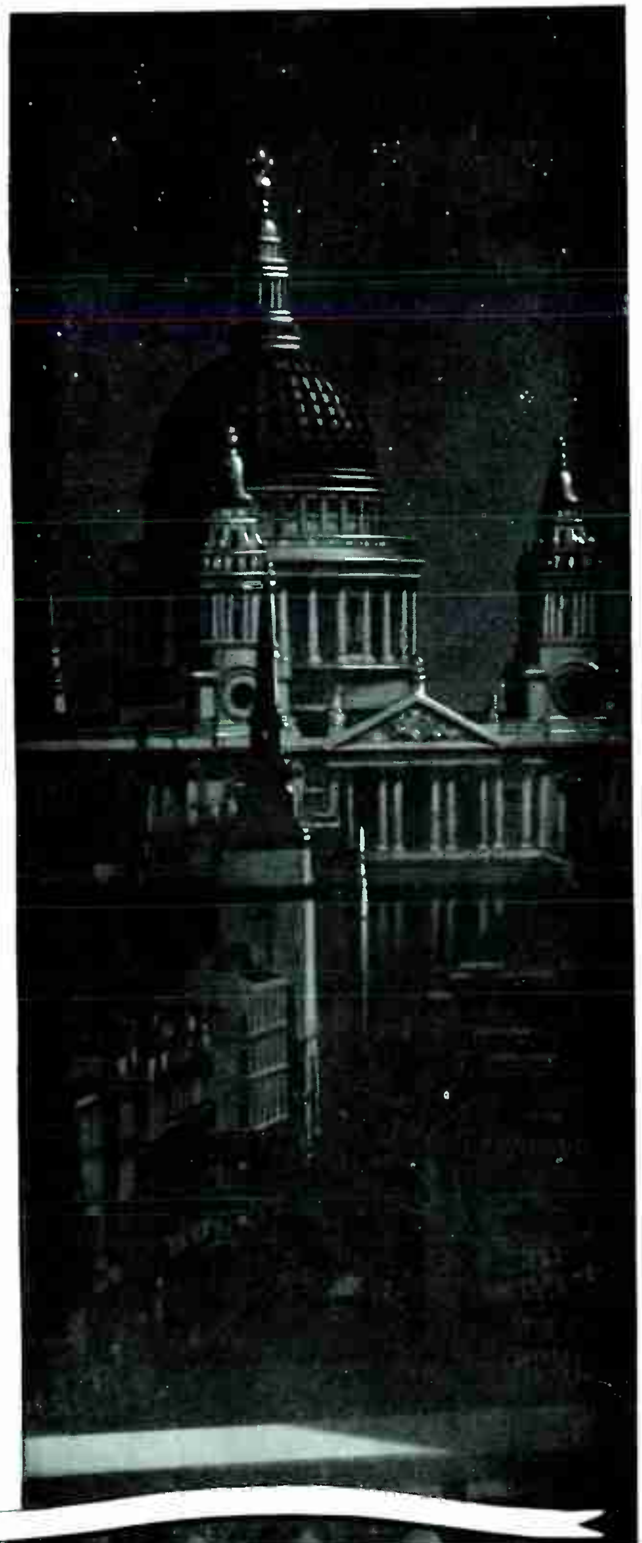

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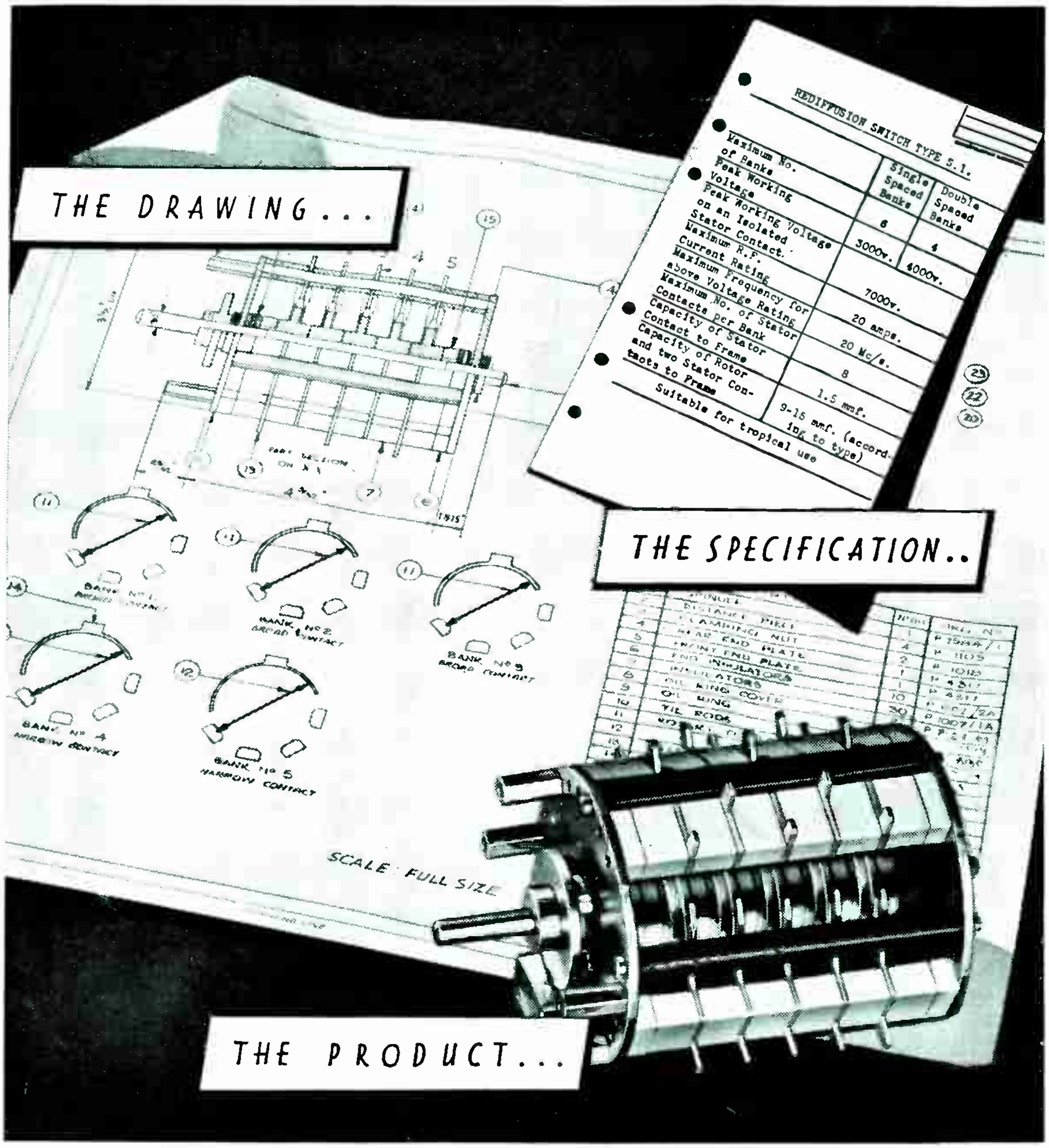

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